Appendix C




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e Bayou Interbasin Transfer Project

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TCB | AECOM

Luce Bayou
Interbasin Transfer Project
Alternative Analysis

Prepared for

Coastal Water Authority

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Abbreviations and Acronyms

AdA	Aldine silt loam, 0 to 2 percent slope
ArcGIS	Geographic Information System Software
ASTM	American Society for Testing and Materials
CCN	Certificate of Convenience and Necessity
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CMSWLI	Closed Municipal Solid Waste Landfill Inventory
CWA	Coastal Water Authority
DOQQ	Digital Ortho Photo Quarter-Quadrangles
DOT	Department of Transportation
EPA	Environmental Protection Agency
ERNS	Emergency Response Notification System
ESA	Endangered Species Act
FEMA	Federal Emergency Management Agency
FHWA	Federal Highway Administration
FIRM	Flood Insurance Rate Maps
FM	Farm-to-Market
FPPA	Farmland Protection Policy Act
GIS	Geographic Information System
GLO	general land office
H-GAC	Houston-Galveston Area Council
IHWNOR	Industrial Hazardous Waste Notice of Registration
IP	individual permit
LEP	Limited English Proficiency
LI	Linguistic Isolation
LiDAR	light detection and ranging
LPST	Leaking Petroleum Storage Tanks
MGD	million gallons per day
MrSID	multi-resolution scale digital
NDD	National Diversity Database
NEWTP	Northwest Water Treatment Plant
NFRAP	No Further Remedial Action Planned
NHD	National Hydrologic Dataset
NLCD	National Land Cover Database
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NPSH	Net Positive Suction Head
NRCS	National Resources Conservation Service
NWI	National Wetland Inventory
NWP	nationwide permits

NWR	national wildlife refuges
O&M	operation and maintenance
OPA	Oil Pollution Act
OSHA	Occupational Safety and Health Administration
OSSF	on-site sewage facilities
PALM	Potential Archeological Liability Map
PJD	preliminary jurisdictional determination
RCRA	Resource Conservation and Recovery Act
RPMs	revolutions per minute
RRC	railroad commission
SCADA	supervisory control and data acquisition system
SH	State Highway
SP	State Parks
SWANCC	Solid Waste Agency of Northern Cook County
TARL	Texas Archeological Research Laboratory
TCB	TCB INC.
TCEQ	Texas Commission on Environmental Quality
TCEs	temporary construction easements
TRA	Trinity River Authority
TRPS	Trinity River Pump Station
TSARP	Tropical Storm Allison Recovery Project
TxDOT	Texas Department of Transportation
TXGLO	Texas General Land Office
U.S.	United States
USACE	U.S. Army Corps of Engineers
USDA	U.S. Department of Agriculture
USFWS	U.S. Fish and Wildlife Service
USGS	United States Geological Survey
UST	underground storage tanks
UTGC	Upper Texas Gulf Coast
VFD	Variable Frequency Drives
Wa	Waller Loam
WMA	wildlife management areas
WPP	water purification plant
WTP	water treatment plant
WWTP	wastewater treatment plant

Section 1
Constraints Analysis

Future water demand in Houston and the surrounding areas will exceed water supply if additional water is not provided. The purpose of the Luce Bayou Interbasin Transfer project is to provide a portion of the needed water supply. A detailed description of the purpose of and need for the project is explained in a purpose and need memo dated January 2007.

Nine alternatives (1 through 6a) were identified to meet the purpose of and need for the Luce Bayou Interbasin Transfer Project. A constraints analysis was performed for these nine alternatives. The alternatives are described below and are depicted on *Exhibit 1*.

Alternative 1 – Lake Livingston through East Fork of the San Jacinto River to Lake Houston

Alternative 1 would meet the purpose of and need for the Luce Bayou Interbasin Transfer Project through conveyance of water from Lake Livingston to Lake Houston. Water would be pumped via a pipeline to discharge into Sand Creek, thence to the East Fork of the San Jacinto River and ultimately Lake Houston. The point of diversion for Alternative 1 would be located on the western shore of Lake Livingston as shown in *Exhibit 1*. An intake structure would be constructed in the main body of the lake. An intake pipe located within the old Trinity River channel would convey the raw water to a pump station located on shore. Various potential locations for the intake and pump station include the Cape Royale peninsula, the Trinity River Authority (TRA) Park north of Cape Royale, and an abandoned marina, currently owned by TRA, south of Cape Royale. Ancillary facilities would include an administration and control building, a maintenance facility, chemical storage and feed facilities, a fuel facility, resident operator housing, a potable water supply, on-site waste disposal, a power supply, communications, access roadways, and related facilities.

The pump station would pump water to Sand Creek via a pipeline, with a sedimentation basin at the discharge end. Based on initial site visits at various public access points to Sand Creek and the East Fork of the San Jacinto River, it appears that Sand Creek would require improvements to accommodate the additional flow. Channel improvements to Sand Creek would extend from the end of the pipeline to the East Fork of the San Jacinto River to accommodate the additional flows. Flow from the pump station would be controlled during times when the natural channels were at high flows. Raw water would then be conveyed down the East Fork of the San Jacinto River to Lake Houston. No channel improvements to the East Fork of the San Jacinto River would be required. Notes and photographs from the site visit to Lake Livingston, Sand Creek, and the East Fork of the San Jacinto River conducted on August 10, 2006, are provided in *Appendix A*.

At the current time, neither the City of Houston nor the Coastal Water Authority (CWA) own water rights for a diversion directly from Lake Livingston. TRA, however, has approximately 178,000 acre-feet of unallocated firm yield available for sale on a long-term water contract basis. Purchase of the water would require a reservation fee equivalent to 30 percent of the anticipated annual fee.

The 2002 United States Geological Survey (USGS) report, *Results of Streamflow Gain-Loss Studies in Texas, With Emphasis on Gains From and Losses to Major and Minor Aquifers*, and the 1969 USGS report, *Quantity and Chemical Quality of Low Flow in the East Fork San Jacinto and West Fork San Jacinto Rivers Near Houston, Texas* conclude that a net gain in the water quantity is realized along the East Fork of the San Jacinto River from Cleveland, Texas to Lake Houston. It is theorized that the river is actually recharged by outcroppings of various aquifers along this portion of the river. However, the report reviewed only the portion of the river from Cleveland, Texas, to Lake Houston.

For the purpose of evaluating alternatives for this project, it was assumed that approximately 0.5 percent of the raw water would be lost to seepage and evaporation per mile of open channel conveyance between Lake Livingston to Lake Houston; however, additional studies would be required to verify this assumption.

Development along the East Fork of the San Jacinto River, particularly the portions closest to Lake Houston, appears viable over the planning period. Based on recent real estate reports, tracts of land in the area have been sold and planning is underway for development of the property.

Raw water conveyed to Lake Houston from Lake Livingston via Sand Creek and the East Fork of the San Jacinto River would be treated at an expanded City of Houston Northeast Water Purification Plant (NEWPP).

Alternative 2 – Trinity River at Capers Ridge through Luce Bayou to Lake Houston

Alternative 2 would meet the purpose of and need for the Luce Bayou Interbasin Transfer Project through conveyance of water from the Trinity River to Lake Houston via a pipeline and canal with discharge into Luce Bayou and subsequently to Lake Houston. The point of diversion in Alternative 2 is the Trinity River near Capers Ridge as shown in *Exhibit 1*. A river intake and pump station would be located along the west embankment of the river. Ancillary facilities would include an administration and control building, a maintenance facility, chemical storage and feed facilities, a fuel facility, resident operator housing, a potable water supply, on-site waste disposal, a power supply, communications, access roadways, and related facilities. For the purpose of this constraints analysis, the site and related facilities are assumed to be similar to those shown in Sections 1 and 2 of *Appendix B*.

The pipeline would convey raw water approximately 3.6 miles along Capers Ridge and would discharge into a constructed canal. A sedimentation basin would be located at the end of the pipeline. For the purpose of this initial constraints analysis, the pipeline and sedimentation basin are assumed to be similar to those shown in Section 3 of *Appendix B*.

A new canal would convey raw water from the pipeline to Luce Bayou, a distance of approximately 2.4 miles. Approximately 15.8 miles of improvements (i.e., deepening and widening) to Luce Bayou would also be required to convey the increased flows. For the purpose of this constraints analysis, the new canal and improvements to Luce Bayou are assumed to be similar to those shown in Sections 4 and 5 of *Appendix B* with the exception that improvements would be needed to the existing Luce Bayou channel downstream of the existing Reidland Reservoir to handle the increased flow. Photographs and notes detailing visits to multiple locations along Luce Bayou and the surrounding area are included in *Appendix A*.

Data regarding potential seepage and evaporation losses in Luce Bayou were not available. For the purpose of evaluating alternatives for this project, it was assumed that approximately 0.5 percent of the raw water would be lost to seepage and evaporation per mile of open channel conveyance from the Trinity River to Lake Houston; however, additional studies would be required to verify this assumption.

Development along portions of Luce Bayou, particularly the portions closest to Lake Houston, appears to be viable over the planning period. Based on recent real estate reports, tracts of land in the area have been sold and planning is underway for development of the property.

Treatment of raw water conveyed to Lake Houston from the Trinity River via Luce Bayou would be assumed to be accomplished at an expanded City of Houston NEWPP. However, growth in the northern portion of Harris County and southeastern portion of Montgomery County may lead to the feasibility of a separate water treatment plant located on the north or northeast side of Lake Houston.

Conveyance of water through Luce Bayou would allow the take point for water treatment to be in Luce Bayou upstream of Lake Houston.

Alternative 3 – Trinity River at Capers Ridge through a Canal to Lake Houston

Alternative 3 would meet the purpose of and need for the Luce Bayou Interbasin Transfer Project through conveyance of water from the Trinity River to Lake Houston via a pipeline and a 16-mile canal with discharge into Luce Bayou near its confluence with Lake Houston. For Alternative 3, the point of diversion is the Trinity River near Capers Ridge as shown in *Exhibit 1*.

A river intake and pump station would be located along the west embankment of the river. Ancillary facilities would include an administration and control building, a maintenance facility, chemical storage and feed facilities, a fuel facility, resident operator housing, a potable water supply, on-site waste disposal, a power supply, communications, access roadways, and related facilities. For the purpose of this constraints analysis, the site and related facilities are assumed to be similar to those shown in Sections 1 and 2 of *Appendix B*.

Raw water would be conveyed approximately 3.6 miles via a pipeline along Capers Ridge and would then be discharged into a constructed canal. A sedimentation basin would be located at the end of the pipeline. For the purpose of this constraints analysis, the pipeline and sedimentation basin are assumed to be similar to those shown in Section 3 of *Appendix B*.

Rather than discharging from the pipe into Luce Bayou, as described for Alternative 2, a constructed canal would be located south of Luce Bayou, and would extend southward approximately 16 miles. The canal would discharge into Luce Bayou near its confluence with Lake Houston.

Data regarding potential seepage and evaporation losses in Luce Bayou were not available. For the purpose of evaluating alternatives for this project, it was assumed that approximately 0.5 percent of the raw water would be lost to seepage and evaporation per mile of open channel conveyance from the Trinity River to Lake Houston; however, additional studies would be required to verify this assumption.

Development in areas south of Luce Bayou, particularly the portions closest to Lake Houston, appears to be viable over the planning period. Based on recent real estate reports, tracts of land in the area have been sold and planning is underway for development of the property.

Treatment of raw water conveyed to Lake Houston from the Trinity River via Luce Bayou is assumed to be accomplished at an expanded City of Houston NEWPP. However, growth in the northern portion of Harris County and southeastern portion of Montgomery County may lead to the feasibility of a separate water treatment plant located on the north or northeast side of Lake Houston. Conveyance of water through Luce Bayou would allow the take point for water treatment to be in Luce Bayou upstream of Lake Houston.

Alternative 4 – Trinity River at Capers Ridge through a Pipeline to Lake Houston

Alternative 4 would meet the purpose of and need for the Luce Bayou Interbasin Transfer Project through conveyance of water from the Trinity River to Lake Houston via a pipeline to Lake Houston. The point of diversion for Alternative 4 is the Trinity River near Capers Ridge as shown in *Exhibit 1.* A river intake and pump station would be constructed along the west embankment of the river. Ancillary facilities would include an administration and control building, a maintenance facility, chemical storage and feed facilities, a fuel facility, resident operator housing, a potable water supply, on-site waste disposal, a power supply, communications, access roadways, and related facilities.

A pipeline would convey the raw water approximately 24 miles directly into Lake Houston. The majority of the pipeline would be constructed adjacent to an existing Houston Natural Gas Company (HNG) pipeline easement located south of Capers Ridge extending southwesterly to a point south of Farm-to-Market Road (FM) 1960. The pipeline would then be located adjacent to an existing Sunoco pipeline easement from FM 1960 to Lake Houston.

There is currently limited development along the pipeline route; however, some residential development does exist near the eastern shore of Lake Houston.

Treatment of raw water conveyed to Lake Houston from the Trinity River via pipeline would assume to be accomplished at an expanded City of Houston NEWPP.

Alternative 4a – Trinity River at Capers Ridge through a Pipeline to NEWPP

Alternative 4a is similar to Alternative 4 except that the pipeline is extended for direct discharge to the NEWPP. Alternative 4a would meet the purpose of and need for the Luce Bayou Interbasin Transfer Project through conveyance of water from the Trinity River to Lake Houston via a pipeline to the NEWPP. The point of diversion for Alternative 4a is the Trinity River near Capers Ridge as shown in *Exhibit 1*. A river intake and pump station would be constructed on the west side of the embankment of the river. Ancillary facilities would include an administration and control building, a maintenance facility, chemical storage and feed facilities, a fuel facility, resident operator housing, a potable water supply, on-site waste disposal, a power supply, communications, access roadways, and related facilities.

The pipeline would be adjacent to an existing HNG pipeline located south of Capers Ridge and would extend southwesterly to a point south of FM 1960. The pipeline would be located adjacent to an existing Sunco pipeline easement from FM 1960 toward Lake Houston, where it would then cross the lake and would discharge directly to the City of Houston NEWPP for a total distance of approximately 32 miles.

There is currently limited development along the proposed conveyance route; however, some residential development does exist near the eastern shore of Lake Houston.

Crossing Lake Houston would likely entail placing the pipeline along the bottom of the lake. Other methods of crossing, including tunneling under the lake and placing the line on a support structure, initially do not appear to be feasible, but could be examined in greater detail if warranted.

It is assumed that raw water conveyed to Lake Houston from the Trinity River via a canal pipeline system would be treated at the expanded City of Houston NEWPP.

Alternative 5 – Trinity River Pump Station through a Canal and Pipeline to Lake Houston

Alternative 5 would meet the purpose of and need for the Luce Bayou Interbasin Transfer Project through conveyance of water from the Trinity River at the CWA Trinity River Pump Station (TRPS) to Lake Houston via a canal and pipeline to Lake Houston. The point of diversion for Alternative 5 is the Trinity River at the existing CWA TRPS facility as shown in *Exhibit 1*. The existing river intake and pump station would be modified and/or expanded along the west embankment of the river. Section 6 of *Appendix B* includes drawings and a description of the existing CWA TRPS. The existing ancillary facilities would require some improvements, but extensive new facilities would not be required.

The canal portion of this alternative would convey the Trinity River raw water approximately 5.9 miles along the existing Dayton Canal system. Significant improvements would be required for the existing Dayton Canal system to provide the capacity required. A new pump station would need to be constructed near State Highway (SH) 146. A pipeline would convey the raw water along SH 146, then to United States (U.S.) Highway 90 where the pipeline would turn to the west, following an existing CenterPoint Energy easement, to discharge into Lake Houston. The total pipeline length would be approximately 15.9 miles.

There is currently limited development along the proposed conveyance route; however, some residential development does exist near Lake Houston's eastern shore.

It is assumed that raw water conveyed to Lake Houston from the Trinity River via a canal pipeline system would be treated at the expanded City of Houston NEWPP.

Alternative 5a – Trinity River Pump Station through Canal and Pipeline to NEWPP

Alternative 5a is similar to Alternative 5 except that the pipeline is extended for direct discharge to the NEWPP. Alternative 5a would meet the purpose of and need for the Luce Bayou Interbasin Transfer Project through conveyance of water from the Trinity River at the CWA TRPS to the NEWPP via a canal and pipeline. The point of diversion for Alternative 5a is the Trinity River at the existing CWA TRPS facility. The existing river intake and pump station would be modified or expanded along the west embankment of the river. Drawings provided in Section 6 of *Appendix B* show the existing CWA TRPS. The existing ancillary facilities would require some improvements; however, extensive new facilities would not be required.

Similar to Alternative 5, the canal would convey water for approximately 5.9 miles where it would then be picked up by the pipeline at SH 146 (where a new pump station would be constructed). The raw water would then be conveyed along SH 146, then to U.S. Highway 90 where it would turn west and follow an existing CenterPoint Energy easement to Lake Houston, cross Lake Houston, and discharge directly to the City of Houston NEWPP. The total length of pipeline would be approximately 23.3 miles.

There is currently limited development along the proposed conveyance route; however, some residential development does exist near the eastern shore of Lake Houston.

Crossing Lake Houston would likely entail placement of the pipeline along the bottom of the lake. Other methods of crossing, including tunneling under the lake and placing the line on a support structure, do not partially appear to be feasible, but could be examined in greater detail if warranted.

It is assumed that raw water conveyed to Lake Houston from the Trinity River via a canal pipeline system would be treated at the expanded City of Houston NEWPP.

Alternative 6 – Trinity River Pump Station through Pipeline to Lake Houston

Alternative 6 would meet the purpose of and need for the Luce Bayou Interbasin Transfer Project through conveyance of water from the Trinity River at the CWA TRPS to Lake Houston via a pipeline. The point of diversion for Alternative 6 is the Trinity River at the existing CWA TRPS facility. The existing river intake and pump station would be modified and/or expanded along the west embankment of the river. Drawings provided in Section 6 of *Appendix B* show the existing CWA TRPS. The existing ancillary facilities would require some improvements; however, extensive new facilities would not be required.

The pipeline would convey raw water in a pipeline that would extend approximately 21.6 miles adjacent to an existing ExxonMobil pipeline easement to FM 2100, and then northward to Foley Road and west directly to Lake Houston.

There is currently limited development along the proposed conveyance route; however, development is occurring along FM 2100.

Treatment of raw water conveyed to Lake Houston from the Trinity River via pipeline would assume to be accomplished at an expanded City of Houston NEWPP.

Alternative 6a – Trinity River Pump Station through a Pipeline to the NEWPP

Alternative 6a is similar to Alternative 6 except that the pipeline is extended for direct discharge to the NEWPP. Alternative 6a would meet the purpose of and need for the Luce Bayou Interbasin Transfer Project through conveyance of water from the Trinity River at the CWA TRPS to the NEWPP via a pipeline. For this alternative, the point of diversion is the Trinity River at the existing CWA TRPS facility. The existing river intake and pump station would be modified and/or expanded along the west embankment of the river. Drawings provided in Section 6 of *Appendix B* show the existing CWA TRPS. The existing ancillary facilities would require some improvements; however, extensive new facilities would not be required.

The pipeline would convey raw water from the Trinity River approximately 24.8 miles along an existing ExxonMobil pipeline easement to FM 2100, northward to Foley Road, and then westward to Lake Houston. The pipeline would cross Lake Houston to discharge directly to the City of Houston NEWPP.

Crossing Lake Houston would likely require placement of the pipeline along the bottom of the lake. Other methods of crossing, including tunneling under the lake and placing the line on a support structure, do not initially appear to be feasible, but could be examined in greater detail if warranted.

There is currently limited development along the proposed conveyance route; however, some development is occurring along FM 2100.

It is assumed that raw water conveyed to Lake Houston from the Trinity River via a canal pipeline system would be treated at the expanded City of Houston NEWPP.

1.1 Environmental Data Analysis

A series of environmental constraints maps were prepared based on land use, mapped biological and sensitive habitats, mapped wetlands and waters of the United States, and socioeconomic data analyses utilizing ArcGIS (Geographic Information System [GIS] software) and are presented as *Exhibits 2* through *6*. The data analyses included plotting available data obtained through data collection, resource and regulatory agency records compilation and review, and limited site reconnaissance. The developed environmental constraints maps were used to evaluate and analyze potential constraints associated with construction of the Luce Bayou Interbasin Transfer Project alternatives.

The constraints analysis was accomplished primarily through a desktop study conducted at a broad scale to refine the number of alternatives identified for consideration at an early stage in the project planning process. As such, the constraints analysis was conducted with the best available data assuming a reasonable level of accuracy for this phase of analysis. In general, field verification was not conducted, although limited field reconnaissance investigations were performed and limited agency consultation efforts were initiated.

The environmental constraints analysis included an assessment of relative potential impacts to various environmental and socioeconomic resources (*Table 3*). The environmental constraints criteria initially analyzed include:

- Length in linear feet of prime farmland soils intersected by each alternative
- Length in linear feet of managed areas and riparian areas intersected by each alternative

- Length in linear feet of National Wetland Inventory (NWI) wetlands mapped by the U.S. Fish and Wildlife Service (USFWS) that are intersected by each alternative

  Note: Wetlands mapped by this method may not be considered jurisdictional by the U.S. Army Corps of Engineers (USACE); however, NWI wetlands are an indicator of the number and extent of wetlands that may be present in the project area.

- Length in linear feet of 100-year floodplains intersected by each alternative, as designated by the Federal Emergency Management Agency (FEMA) or through a review of Tropical Storm Allison Recovery Project (TSARP) floodplain data
- Length in linear feet of the mapped 100-year floodplain that also would intersect mapped NWI wetlands along each alternative
- Socioeconomic resource evaluation for each alternative based on U.S. Census data describing income, race, education, and language skill level for populations in proximity to the alternatives
- Number of hazardous waste and/or permitted sites identified by TCEQ superfund data within 500 feet of the centerline for each alternative
- Number of mapped oil and gas wells from Railroad Commission of Texas and Geomap® data within 500 feet of each alternative

For each alternative, relevant environmental constraints were identified and a qualitative assessment of the potential for these constraints to influence or be affected by construction of each alternative was developed. Where possible, an assessment of the need for detailed studies, field investigations, and additional data collection was also developed.

1.1.1 Agricultural Data

Congress enacted the Farmland Protection Policy Act (FPPA) as a subtitle of the 1981 Farm Bill with the purpose of "[minimizing] the extent to which federal programs contribute to the unnecessary conversion of farmland to nonagricultural uses," (7 United States Code [USC] 4201, et seq.). The U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) administers the FPPA. Prime farmland soils are soils that have chemical and physical characteristics as determined by USDA NRCS as quality farmlands.

Soils and farmland data were obtained from the USDA NRCS. The following USDA NRCS soil surveys were used to gather information regarding soils crossed by the alternatives:

- 1976 Soil Survey of Harris County, Texas
- 1996 Soil Survey of Liberty County, Texas
- 1988 Soil Survey of Polk and San Jacinto Counties, Texas

Soil mapping units for each county were plotted in ArcGIS, and the county-specific soil surveys were used to categorize soils as either mapped prime farmland or not. The total length (in feet) of each alternative mapped as crossing prime farmlands soils was calculated and described (*Table 3*).

The intersection of each alternative with areas that are mapped as prime farmland soils were measured and the length of prime farmland soils that intersect each alternative ranged from approximately 800 linear feet (Alternative 1) to 113,500 linear feet (Alternative 5a), as shown on *Exhibit 2*. Portions of Alternatives 1 and 2 would be within an existing surface water feature. In general, although impacts to prime farmland soils would occur during implementation of the alternatives, these impacts are expected to be minimal. A new canal would be constructed for Alternative 3 and this would permanently remove areas classified as prime farmlands. Alternatives 4 and 4a and Alternatives 6 and 6a would be subterraneous, which would result in temporary construction-related impacts to prime farmland soils. Alternatives 5 and 5a would include both a subterraneous pipeline and the construction of a new canal section. Alternative 5a would have the greatest impact to prime farmland soils, compared to the other project alternatives.

1.1.2 Biological and Habitat Data

Biological and habitat data evaluated in this analysis includes lengths of alternatives that transverse managed areas and riparian habitat, based on interpretation of aerial photography (*Table 3*).

1.1.2.1 Managed Areas

Managed areas include national preserves, national forests, national wildlife refuges (NWRs), wildlife management areas (WMAs), state parks (SP), county parks, Indian reservations, privately managed lands, and others. These data were collected from a number of sources including USGS topographic maps, the Texas General Land Office (TXGLO), and the USFWS. Boundaries for these areas were identified and were compared to the location of the alternatives. The length of managed areas traversed by each alternative was calculated.

Managed areas that the alternatives intersect include Sam Houston National Forest, Sam Houston WMA, Lake Houston SP, Trinity River NWR, Dwight D. Eisenhower SP, and Alexander Deussen SP, as shown on *Exhibit 3*.

Alternative 1 would transverse the Sam Houston National Forest and Sam Houston WMA for a majority of the alignment for a distance of approximately 203,800 linear feet. Alternatives 2, 3, 4, and 4a extend across properties included as part of the Trinity River NWR acquisition corridor for a distance of approximately 9,900 linear feet. The USFWS has developed a plan to acquire floodplain areas within a corridor identified along the Trinity River for conservation as part of the Lower Trinity River Floodplain Habitat Stewardship Program and would acquire these lands when funding becomes available. Alternatives 6 and 6a extend across Dwight D. Eisenhower SP and Alexander Deussen SP for a distance of approximately 14,800 linear feet.

1.1.2.2 Riparian Areas

Riparian habitat was assessed for Alternatives 1 and 2 because these alternatives include a riparian channel. Riparian habitat was interpreted by biologists using ArcGIS to compare the 1995 and 2004 Digital Ortho Photo Quarter-quadrangles (DOQQs) to the alternatives. The color infrared imagery in the DOQQs was used to identify areas with signatures that could indicate the presence of riparian habitat.

The analysis of true color photography and DOQQ aerials in ArcGIS resulted in the identification of riparian habitat along Alternatives 1 and 2. Approximately 325,000 linear feet of riparian habitat were identified along Alternative 1, and approximately 106,500 linear feet were identified along Alternative 2.

1.1.3 Waters of the United States, Including Wetlands

The Clean Water Act of 1972 and the Rivers and Harbors Act of 1899 contain provisions enacted to regulate impacts upon wetlands and waters of the United States. Waters of the United States, including wetlands, are regulated by the USACE under provisions established under Section 404 of the Clean Water Act. Section 404 of the Clean Water Act requires authorization from the USACE to discharge dredged or fill material into waters of the United States and jurisdictional wetlands. Section 10 of the Rivers and Harbors Act regulates those acts that affect the course, location, or condition of a navigable water of the United States. Permits related to both regulations are issued by the USACE. The Section 404 definition of wetlands is, “Those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support a prevalence of vegetation typically adapted for life in saturated soil conditions.” The U.S. Supreme Court opinion in the *Solid Waste Agency of Northern Cook County* (SWANCC) *v. United States Army Corps of Engineers* case was that the USACE’s jurisdiction did not extend to isolated wetlands if they are not “adjacent” to navigable waters. The USACE-Galveston District issued guidance to staff on the subject of adjacent versus isolated wetlands in a memorandum dated February 13, 2001 (Policy Number 01-001). The memorandum states that wetlands having a hydrological connection to waters of the United States (including being located within the 100-year floodplain) are generally considered adjacent, and therefore, jurisdictional.

The guidance referenced above is current as of the time of publication of this alternatives analysis. It should be noted that a U.S. Supreme Court decision could alter the current guidance and affect the permitting of waters of the United States, including wetlands, that may be associated with the proposed project. The court cases, *United States v. Rapanos* and *United States v. Carabell*, could affect the determination of “significant nexus” to waters of the United States Pending guidance may eventually indicate that wetlands without a significant nexus to regulated waters of the United States not be considered jurisdictional, regardless of location within the 100-year floodplain.

Potential waters of the United States, including wetlands, were quantified using USFWS NWI maps, the USGS National Hydrologic Dataset (NHD), and FEMA floodplain maps. Stream and canal crossing data were obtained from the NHD. The NHD is a comprehensive set of digital spatial data that contain information about surface water features such as lakes, ponds, streams, rivers, springs, and wells. The NHD was used to calculate the number of waterbody crossings and the length of stream impacts. The number of stream crossings was determined by overlaying the NHD data on the corridors of the project alternatives. Stream crossings were counted for each alternative, and if a natural waterbody to be used as a water conveyance, the linear distance of the affected portions of the waterbody was calculated (*Table 3*). Drainage crossings that discharge into existing channels (Luce Bayou and East Fork San Jacinto River) were not counted as a “crossing.”

Alternatives 1 and 2 would be partially constructed within jurisdictional surface water features, East Fork San Jacinto River and Luce Bayou. The centerline of these alternatives intersected the lowest number of drainages or canals, two and one, respectively. Alternative 3 would intersect five surface water features which appear to be primarily non-jurisdictional irrigation canals. Alternatives 4 (4a), 5 (5a), and 6 (6a) would intersect 10, 16, and 20 drainage or canal crossings, respectively (*Exhibit 4*).

The USFWS established the NWI in 1974 to develop and provide resource managers with information on the location, extent, and types of wetlands and deepwater habitats. While useful in preliminary assessment phases, the NWI data tend to overestimate wetland acreages for wetlands shown, and smaller, more isolated wetlands may not be identified. NWI data are available in GIS formats. Potential wetland types were identified using USFWS NWI maps. The linear distance of wetlands intersected by the project alternatives was measured and acreages calculated for each alternative.

NWI maps may not represent jurisdictional wetlands regulated by the USACE. Floodplain data for Harris County were obtained from the TSARP and FEMA provided floodplain data for Liberty and San Jacinto Counties (*Exhibit 4*). FEMA Flood Insurance Rate Maps (FIRM) were used to calculate the length of floodplain mapped for each alternative in the counties of Liberty and San Jacinto. Wetlands within mapped floodplains are more likely to be considered adjacent to waters of the United States, and as such, are more likely to be considered jurisdictional by the USACE, per guidance from the USACE-Galveston District. To quantify the amount of wetlands within the floodplain, FEMA floodplain data were combined with NWI wetland data and the acreage of NWI wetlands within the 100-year floodplain was measured. For this reason, the length of NWI wetlands intersecting each alternative, the length of 100-year floodplain intersecting each alternative, and the length of NWI wetlands within the 100-year floodplain intersecting with each alternative were also calculated.

The linear feet of alignment intersecting NWI-mapped wetlands ranged from approximately 8,800 feet (Alternative 4) to approximately 36,400 feet (Alternative 2). Although no NWI-mapped wetlands were identified along Alternative 1, there is a potential that wetland fringe occurs along the channel and the results may not reflect this condition, if present.

Alternatives 1 and 2 would be constructed within an existing waterbody. Alternative 1 would be composed of approximately 327,900 linear feet of existing stream, while Alternative 2 would be composed of approximately 106,500 linear feet of existing stream. These streams would then be used for water conveyance. The floodplain associated with these existing streams would intersect Alternatives 1 and 2 for the longest length, approximately 319,900 and approximately 120,200 linear feet, respectively. The lengths of floodplains intersecting the other alternatives ranges from approximately 14,300 to 31,200 linear feet.

Alternative 2 exhibits the greatest number of linear feet of NWI-mapped wetlands within its corridor. Because a larger proportion of Alternative 2 is also within the 100-year floodplain, a larger portion of the NWI wetlands along Alternative 2 could be considered jurisdictional by the USACE. The total length of Alternative 2 that intersects with NWI wetlands within the 100-year floodplain is approximately 34,100 linear feet. Alternatives 1 and 4 did not have overlapping NWI wetlands and floodplains. The NWI-mapped wetlands for other alternatives ranged from approximately 2,400 linear feet to 13,600 linear feet.

During limited field reconnaissance in the vicinity of Alternatives 2 and 3, areas mapped as NWI wetlands were active agricultural fields which may not exhibit the mandatory parameters of jurisdictional wetlands.

1.1.4 Environmental Justice and Socioeconomic Data

Collectively, social and economic indicators are often referred to as socioeconomics. Much of the information that assists in evaluating the socioeconomic status of a given population is available from the U.S. Census Bureau on a national, state, or regional level. Site-specific socioeconomic data are available from the U.S. Census Bureau on a county, census block, and census tract level. More detailed information regarding a community’s educational institutions, fire and rescue or medical services, and local employment information is typically available from state or county governmental offices such as local chambers of commerce.

The parameters evaluated for this constraints analysis included race, income, language, and education data. These data were compiled from the 2000 Census by the U.S. Census Bureau available online. The data were evaluated at the census tract level for each alternative. These tracts were also compared to the county, state, and national data to provide a basis for understanding the significance of potential impacts. The census tracts evaluated for each Alternative include:

- Alternative 1: Census Tracts 2001.02, 2002, and 2003 (San Jacinto County); Census Tract 2516 (Harris County); and Census Tracts 7001 and 7003 (Liberty County)
- Alternative 2: Census Tract 2516 (Harris County); Census Tracts 7003, 7004, and 7008 (Liberty County)
- Alternative 3: Census Tract 2517 (Harris County); Census Tracts 7004, 7008, and 7009 (Liberty County)
- Alternative 4: Census Tracts 2504, 2517, and 2520 (Harris County); Census Tracts 7004, 7008, 7009 and 7010 (Liberty County)

- Alternative 5 (5a): Census Tracts 2504 and 2520 (Harris County); Census Tracts 7010 and 7011 (Liberty County)
- Alternative 6 (6a): Census Tracts 2518, 2519, 2520, 2521, and 2527 (Harris County) and Census Tracts 7101 and 7011 (Liberty County)

The locations of the census tracts that are intersected by the alternatives are depicted in *Exhibit 5*.

1.1.4.1 Environmental Justice

Executive Order 12898, *Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations*, was enacted on February 11, 1994, and mandates that federal agencies identify and address, as appropriate, disproportionately high and adverse human health or environmental effects of programs on minority and low-income populations. A minority population is defined as a group of people and/or a community experiencing common conditions of exposure or impact that consists of persons classified by the U.S. Census Bureau as Black or African-American; Asian; American Indian or Alaska Native; Native Hawaiian or other Pacific Islander; Hispanic or Latino; or other non-white persons, including those persons of two or more races. A low-income population is defined as a group of people and/or a community that, as a whole, lives below the national poverty level. The poverty threshold for a family of four people in 1999, as defined by the U.S. Census Bureau, was a total annual household income of $17,209, which increased to $19,307 in 2004. The poverty guideline for a family of four people in 2000, as defined by the U.S. Department of Health and Human Services, was a total annual household income of $17,050, which increased to $20,000 in 2006. Disproportionately high and adverse effects on minority or low-income populations generally mean an adverse effect that is predominantly borne by a minority population and/or low-income population, or would be suffered by the minority population and/or low-income population, and is appreciably more severe or greater in magnitude than the adverse effect that would be suffered by the non-minority population and/or non-low-income population. Available demographic data for percent minority and low-income populations from the 2000 U.S. Census is provided in *Table 1.*

One census tract, Census Tract 7009 in Liberty County, had more than 50 percent minority as compared to the white population while the remaining census tracts intersected by the alternatives had less than 26 percent minority. Alternatives 1, 5, 6, and 6A would not intersect Census Tract 7009; therefore, would not intersect minority tracts. The alternatives that would intersect the minority tract ranged from approximately 74,300 linear feet to 26,400 linear feet, as shown on *Exhibit 5.*

The percent minority populations in census tracts that are crossed by alternatives range from 4 percent to 55 percent, which is lower than the national average and consistent with the state and county levels. The census tract with the highest percentage of minority population is Census Tract 7009 in Liberty County. Alternatives 2, 3, 4, and 4a intersect this census tract.

The majority of the populations within the census tracts intersected by the evaluated alternatives have annual incomes above the poverty level. All census tracts, with the exception of Census 2002 in San Jacinto County, had more than 84 percent of the population above the poverty level, which is consistent with Harris and Liberty counties. Approximately 81 percent of the population living in Census Tract 2002 in San Jacinto County is above the poverty level. San Jacinto County is also recorded as having more than 81 percent of the population above the poverty level. The national percentage living below the 1999 poverty level is 12 percent, and the state percentage is 15 percent. The percentage of the population living below the poverty level ranges from less than 1 percent to 19 percent in the census tracts intersected by the evaluated alternatives.

The median household income for populations within the U.S. is $41,994. The median household income for populations within the alternative census tracts ranges from $34,205 to $72,050.

Alternative 2 crosses areas with the lowest median household income at $34,205 based on census tract data, which is higher that the San Jacinto County median household income of $32,220.

No low-income census tracts would be intersected by the alternatives.

1.1.4.2 Language

Executive Order 13166, *Improving Access to Services for Persons with Limited English Proficiency*, sets a framework to improve access to federally-conducted and federally-assisted programs and activities for persons who, as a result of national origin, are limited in their English proficiency. *Table 1* illustrates the percentage of the population with Limited English Proficiency (LEP) in the census traits for the project alternatives.

The percentage of the population with LEP within Harris, Liberty, and San Jacinto Counties are approximately 18, 5, and 3 percent, respectively. Percent Linguistic Isolation (LI) within Harris, Liberty, and San Jacinto Counties are approximately 10, 2, and 1 percent, respectively. Census Tracts 7001, 7003, and 7009 have a higher percent LEP and LI when compared with county level data. The remaining census tracts have lower percentages of LEP and LI than their respective counties. Areas along the alternatives have an overall lower percentage of LI and LEP as compared to the national averages.

1.1.4.3 Education

The census tracts that intersect the alternatives exhibit comparable education levels with their respective counties, as shown on *Table 2*. With one exception (i.e., Census Tract 2504 located in Harris County), more than 30 percent of the population within the census tracts that intersect the alternatives has completed high school or the equivalent. Census Tract 2504 had 19 percent of the population with a high school education or the equivalent, which is comparable to the 21.64 percent in Harris County. Similarly, the 30.13 to 44.71 percent of the population within the census tracts that intersect the alternatives of Liberty County had completed high school or equivalent, which is comparable to the 36 percent of the population in Liberty County that had completed high school or equivalent.

1.1.5 Hazardous Materials Data

Hazardous materials and hazardous waste are defined by a number of acts, laws, and regulations. In general, hazardous materials and hazardous waste include substances that, because of their quantity, concentration, or physical, chemical, or infectious characteristics, may present substantial danger to the public health, welfare, or the environment when released. The U.S. Environmental Protection Agency (EPA) regulates hazardous chemicals, substances, and wastes under the Resource Conservation and Recovery Act (RCRA), the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), and the Toxic Substances Control Act. Underground Storage Tanks (USTs) containing regulated substances, including petroleum products and those hazardous substances included in CERCLA are subject to the requirements of RCRA Subtitle I. Tanks used to store hazardous wastes are regulated under RCRA's hazardous waste regulations. Texas has an approved UST program, meaning owners and operators of USTs systems are subject to both Federal and state requirements. No single comprehensive regulation governs aboveground storage tanks. Federal laws that regulate aboveground storage tanks include the CWA, the Oil Pollution Act (OPA), the Clean Air Act, and RCRA. The specific regulatory requirements depend on the substances contained in the tanks.

A Superfund site is a hazardous waste site that is part of the EPA's Superfund Program. Known Superfund site data from the Texas Commission on Environmental Quality (TCEQ) database were plotted in ArcGIS. The number of Superfund sites within 500 feet of each alternative was calculated. Oil and gas industry mapping service data were obtained from GeoMap and the Railroad Commission of Texas (RRC) to identify the presence of oil and gas wells along the alternatives. The number of oil and gas well sites within 500 feet of each alternative was included in the analysis. Data on pipeline corridors were acquired from the RRC and plotted in ArcGIS. The alternatives were mapped and the number of pipeline corridor crossings for each alternative was calculated. Superfund sites, oil and gas wells, and oil and gas pipelines are depicted on *Exhibit 6.*

Table 1. Socioeconomic Data for the Project Alternatives

	White	Minority	Percent LEP	LI	Poverty Level (percent)		Median Household Income (1999)	Alternative
	percent				Above	Below		
United States	69	31	8	4	88	12	41,994	
Texas	52	48	14	7	85	15	39,927	
Harris County	42	58	18	10	85	15	42,598	
Liberty County	75	25	5	2	86	14	38,361	
San Jacinto County	81	19	3	1	81	19	32,220	
San Jacinto County								
Census Tract 2001.02	79	21	2	1	83	17	28,592	1
Census Tract 2002	79	21	2	0.11	81	19	34,205	1
Census Tract 2003	82	18	1	1	81	19	30,871	1
Liberty County								
Census Tract 7001	68	32	17	7	86	14	37,396	1
Census Tract 7003	76	24	9	4	84	16	39,360	2
Census Tract 7004	96	4	0.89	0	91	9	45,442	1, 2, 3, 4, 4a
Census Tract 7008	84	16	3	0.73	88	12	44,743	2, 3, 4, 4a
Census Tract 7009	45	55	6	3	87	13	39,107	2, 3, 4, 4a
Census Tract 7010	72	28	3	1	84	16	39,563	4, 4a, 5, 5a, 6, 6a
Census Tract 7011	85	15	2	0.85	91	9	49,375	5, 5a, 6, 6a

Table 1. Socioeconomic Data for the Proposed Project Alternatives *(continued)*

	White	Minority	Percent LEP	LI	Poverty Level (percent)		Median Household Income (1999)	Alternative
	percent				Above	Below		
Harris County								
Census Tract 2504	79	21	4	0.32	98	2	72,050	4a, 5a
Census Tract 2510	85	15	5	1	91	9	52,228	6, 6a
Census Tract 2516	93	7	2	3	94	6	51,941	1, 2, 3, 6 , 6a
Census Tract 2517	90	10	6	3	95	5	52,848	2, 3, 4, 4a, 5, 5a
Census Tract 2518	87	13	2	2	96	4	47,083	6, 6a
Census Tract 2519	85	15	4	2	91	9	61,098	6a
Census Tract 2520	76	24	3	2	96	4	60,500	6a
Census Tract 2521	83	17	5	2	99	0.30	47,311	6a
Census Tract 2527	74	26	8	3	88	12	41,409	6a

U.S. Census Bureau 2000

Table 2. Level of Education Completed by Populations Living Along the Alternatives (percent)

	No Schooling Completed	Not Completed High School	High School Graduate (includes equivalency)	Some College, No Degree	Associate Degree	Bachelor's Degree	Graduate or Professional School Degree
Harris County	2.98	22.39	21.64	21.32	4.74	17.92	9.02
Liberty County	1.60	28.84	36.17	22.14	3.19	5.35	2.71
San Jacinto County	1.36	26.04	38.56	21.93	2.54	6.35	3.21
San Jacinto County							
Census Tract 2001.02	2.03	26.44	40.71	20.13	2.05	5.90	2.75
Census Tract 2002	0.74	22.13	34.18	24.91	2.94	10.29	4.80
Census Tract 2003	0.62	23.07	38.81	22.42	4.37	6.53	4.18
Liberty County							
Census Tract 7001	1.56	31.95	39.06	20.63	2.47	1.69	2.64
Census Tract 7003	2.55	30.37	35.47	22.92	1.97	4.46	2.25
Census Tract 7004	0.45	23.68	44.71	23.23	2.61	3.24	2.08
Census Tract 7008	1.58	19.38	37.15	27.36	4.43	7.02	3.08
Census Tract 7009	1.64	45.62	30.13	17.26	3.58	1.43	0.34
Census Tract 7010	0.80	29.01	34.23	25.97	2.45	5.10	2.45
Census Tract 7011	0.54	20.95	39.43	24.77	6.23	6.06	2.02
Harris County							
Census Tract 2504	1.02	4.51	19.04	30.32	8.72	26.01	10.38
Census Tract 2516	0.00	21.17	32.23	31.47	6.21	6.89	2.03
Census Tract 2517	1.09	14.58	37.29	30.37	3.45	10.37	2.85
Census Tract 2518	0.57	13.18	42.84	29.95	2.46	7.77	3.22

Table 2. Level of Education Completed by Populations Living Along the Alternatives (percent) *(continued)*

	No Schooling Completed	Not Completed High School	High School Graduate (includes equivalency)	Some College, No Degree	Associate Degree	Bachelor's Degree	Graduate or Professional School Degree
Census Tract 2519	1.24	13.51	31.10	28.66	5.90	13.40	6.19
Census Tract 2520	0.00	20.31	30.80	21.97	1.73	16.35	8.84
Census Tract 2521	3.73	17.00	34.81	28.75	3.96	8.73	3.03
Census Tract 2527	0.47	20.25	44.57	22.92	5.57	5.33	0.89

U.S. Census Bureau 2000

One Superfund site is listed by the TCEQ and is located within 500 feet of Alternative 5. The site name is Liberty Waste Disposal Company or the Cox Road Dump Site. The EPA ID is TXD9879871789. This site was operated as an industrial waste disposal facility from 1969 until 1983. The landfill is 83 acres on the west side of County Road 491 (Cox Road) about one mile north of FM 1413. The site was originally used to landfill tank bottoms and filter cake from petroleum companies, using a trench and fill method. At the close of operations, the landfill was capped with soil dug up from a portion of the site. Since then, the three-foot layer of topsoil has been eroded and the buried waste has been exposed. Runoff from the site drains into the Trinity River through a series of ditches that crisscross the property. Analytical results of soil and water samples indicate the presence of arsenic, barium, boron, chromium, lead, and mercury, Aroclor 1016, cadmium, cobalt, cyanide, phenol, toluene, xylene, and the pesticide 4,4-DDE. On August 25, 2006, a legal notice was published in the Texas Register, (31 TexReg 7021), officially deleting the site from the state Superfund registry in accordance with 30 TAC §335.344(c) and 30 TAC §361.189(a). The site was accepted into the Voluntary Cleanup Program in 2006 and site remediation will occur as directed under this program.

The number of oil and gas wells within 500 feet of the centerline of each alternative ranged from 0 to 21 and the number of pipeline corridor crossings for each alternative ranged from 12 to 23.

1.2 Preliminary Engineering Analysis

Each alternative was evaluated with respect to various preliminary engineering issues, listed below:

- Alternative intake locations, types, configurations, and materials of construction
- Alternative pump station locations, types, and configurations
- Preliminary hydraulic design of intake, pumping system, and transmission system calculations and determination of preliminary intake, pump, pipe, and open channel sizes
- Silt control measures at the pump station and along open channels
- Silt dewatering and disposal alternatives
- Geotechnical issue investigation and development of scopes of work for field investigations, laboratory testing, and engineering analysis required for preliminary design
- Preliminary civil/site issues based on initial site/route visits
- Preliminary site plan for each alternative pump station site
- Structural and electrical issues
- Instrumentation and communications alternatives
- Mechanical equipment issues
- Pipe material alternatives
- Corrosion and cathodic protection alternatives
- Alternative sources of power supply to the pump station and ancillary facilities
- Emergency power supply considerations
- Required actions with alternative power suppliers
- Potable water and sanitary/waste disposal for pump station site facilities
- Issues related to areas that may be potentially contaminated with hazardous and toxic materials

- Constructability
- Site access
- Security required for pump station site and along transmission route
- Pipeline and private utility crossing issues including relocations
- Highway and county roadway crossing issues
- Railroad crossing issues
- Potential land acquisition issues based on initial meetings with area landowners
- Feasibility level estimates of probable cost for alternatives including construction, mitigation, land acquisition, engineering, legal, administrative and operations, maintenance, and repair

At the conclusion of the preliminary engineering analysis, scopes of work for detailed field investigations and assessments were initiated. The engineering analyses also included the development of maps and exhibits of alternatives, pump station site plans for each alternative configuration, and a conveyance system plan for each route alternative.

Based on a review of the Luce Bayou Water Transfer project as described by reports dating from the 1970s and 1980s including pump station configuration, pipeline, stream, and canal conveyance facilities, the existing CWA's TRPS plans provided by (Kellogg, Brown and Root) KBR, and available engineering and environmental data, a number of specific engineering issues were identified and needed to be addressed. Issues ranging from mechanical, structural, and electrical to general site access, and constructability have been evaluated and described in the following sections.

1.2.1 General Issues

The following sections describe the general issues involved with designing, building, and maintaining conveyance and facilities related to each alternative route. While the results are comprehensive, a more detailed analysis will be required when the most practical alternative is selected.

1.2.1.1 Intake Structures

Intake structures fall into two basic types: lake intakes and river intakes.

Lake Intake

Alternative 1 is the only alternative that utilizes a lake intake. Regarding Alternative 1, a Lake Livingston map depicting topographic features of submerged and non-submerged areas was reviewed. The old Trinity River channel contains the deepest waters of the lake. It is understood that during drought of record with all permitted waters diverted for their intended uses, the lake level could be extremely low, perhaps limited to flows just in the old channel. Therefore, the location of a lake intake in the old channel provides a greater potential to divert water from the lake during drought periods. The old channel weaves through the main body of the lake with a portion located relatively close to the peninsula containing the Cape Royale development (see Section 8 of *Appendix B*). The Cape Royale development is relatively close to Sand Creek which is a tributary of the East Fork of the San Jacinto River which in turn feeds into Lake Houston. Therefore, the Cape Royale development area and Sand Creek forms the basic diversion and conveyance corridor for Alternative 1.

Cape Royale is a private, gated golf community on the western shore of Lake Livingston populated with moderately to expensively priced homes. The location of a lake intake immediately offshore from this development, a pump station located on shore, and a raw water transmission line located through the development would, in all likelihood, receive considerable opposition from the homeowners. Therefore, three alternative pump station and intake locations were identified. One is an intake located north of Cape Royale with a pump station located at Wolf Creek Park which is owned and operated by the TRA. The second alternative places the pump station and intake in the Cape Royale community with an intake located directly offshore. The third alternative places the intake south of Cape Royale at the site of an abandoned marina. This site is currently owned by the TRA as well. A raw water conveyance line could be routed from these three alternative sites to Sand Creek.

Regarding the lake intake, depending on the depth of the lake and the vertical variation of the water quality, a tower intake structure allowing water to be drawn off from selected levels was considered. If the stratification of water quality in the lake is not an issue, then a simpler submerged intake may be investigated. Stratification and water quality issues related to depth need to be evaluated. Sediment deposition and transport rates in the lake need to be investigated to assure that the lowest levels of the intake do not become clogged or buried over time.

Various materials may be used for pipe including steel and concrete. Structures will likely be constructed using reinforced concrete. Structural steel piles may be used in the construction of any structures and may also be incorporated into the permanent structures. Due to the volatility of construction materials and labor availability and costs, a review and analysis of the advantages and disadvantages of each type of construction materials would not be appropriate at this time. An evaluation of alternative construction materials will be completed during subsequent phases.

Initial issues related specifically to this lake alternative include the following.

- Water depths in the old Trinity River channel under various conditions, including drought of record and flood conditions
- Water quality in the various water strata in the lake throughout the year and during various water level conditions
- Sedimentation deposition and transport rates in the lake
- Aquatic species requiring protection at the intake
- Public support for location of intake, pump station, and transmission line
- Available land for on-shore pump station
- Acceptable intake structure configuration and location for safe boating and other water uses of Lake Livingston

River Intake

Alternatives 2, 3, 4, and 4a include a new intake constructed on the western bank of the Trinity River at Capers Ridge. The intake is incorporated into the pump station structure. For the purpose of this report, the intake structure is assumed to be similar to that shown in the plans developed by KBR contained in Section 2 of *Appendix B.*

Alternatives 5, 5a, 6, and 6a include utilizing the existing intake structure at the CWA TRPS with possible modifications and improvements to the existing intake structure and pump configuration. The drawings of the existing CWA pump station are included provided in Section 6 of *Appendix B*. In addition, photographs of the existing pump station are in *Appendix A* under the site visit dated July 19, 2006.

The river intake structures will likely be incorporated into the pump station, and constructed using reinforced concrete. Structural steel piles may be used in the construction of any structures and may also be incorporated into the permanent structures. Due to the volatility of construction materials and labor availability and prices, at this stage of the project, a review and analysis of the advantages and disadvantages of each type of construction materials would not be appropriate at this time. A complete evaluation of alternative construction materials will be conducted during subsequent phases.

Initial issues related specifically to these river intake alternatives include the following.

- Water depths in the Trinity River under various conditions, including drought of record and flood conditions
- Sedimentation deposition and transport rates in the Trinity River
- Aquatic species requiring protection at the river intake
- Public support for the location of the intake, pump station, and transmission line
- Acceptable intake structure configuration and location for safe navigation of the Trinity River
- Land available within Trinity River (General Land Office Easement)
- Bank stability, erosion, and other geotechnical considerations

Initial preliminary engineering issues common to all alternatives include the following.

- A less open system where each pump cell is isolated and could be shut off for inspection or maintenance without shutting the entire pump station down. This could be achieved by having separate sluice gates for each pump cell for example.
- In addition to bar screens, investigation into the use of fine screens should be conducted. Additional removal of grit would improve the longevity of the pumps due to wear as well as reducing siltation in the channel downstream of the pumps.
- Investigation as to the size and structure of each pump cell to assure that it does not induce cavitation or inefficient operation of the pumps.
- The option of being able to select the vertical location from which water is drawn into the station for maximum efficiency
- Selection of materials of construction for strength, durability, availability, and cost

1.2.1.2 Pump Station

The locations of the pump stations for the various alternatives are discussed in the previous section on intakes. This section discussed the various characteristics that were evaluated for each of the alternative sites. Selection of the number of pumps and the specific pumping capacity of each pump would be determined during preliminary design. For the purpose of this report, the configuration of the pump station at Capers Ridge for Alternatives 2, 3, 4, and 4a is assumed to be similar to the design shown in Section 2 of *Appendix B*. The configuration of the existing pump station at the CWA TRPS which would be incorporated into Alternatives 5, 5a, 6, and 6a is shown provided in Section 6 of *Appendix B*. For the purpose of this report, it is assumed that the configuration of the pump station for Alternative 1 may be somewhat similar to that of Alternatives 2, 3, 4, and 4a with modifications to accommodate the lake intake configuration.

Initial system requirements were identified, as well as the initial route corridors of the pipeline, canal, and channel improvements for each alternative in previous sections of this report. The length of each conveyance method was determined from available maps, and a profile of each route corridor was estimated using preliminary USGS data. The profiles created for each alternative are located in

Section 7 of *Appendix B*. The pump station firm capacity that would be provided by each of the alternatives in this project is determined from the flows identified in the project *Purpose and Need Memorandum*. Flow requirements are 200 million gallons per day (MGD) for Phase I and 400 MGD for Phase II. From this data, preliminary pipeline and canal sizes were identified and system static and dynamic heads were developed in order to determine power requirements. These power requirements can be seen in *Appendix D*.

Structures will likely be constructed using reinforced concrete. Structural steel piles may be used in the construction of any structures and may also be incorporated into the permanent structures. Due to the volatility of construction materials and labor availability and prices, at this stage of the project, a review and analysis of the advantages and disadvantages of each type of construction materials would not be appropriate at this time. A complete evaluation of alternative construction materials will be conducted during subsequent phases.

In summary, initial preliminary engineering issues for pump stations include the following items:

- Number of pumps and flow rate of each pump as impacted by total pumping capacity, firm pumping capacity, phased pumping capacity, and water system delivery/operational requirements
- Total dynamic head as impacted by pipeline and canal hydraulics, and static head conditions
- Energy usage including operating pumps at maximum efficiency, and potential use of Variable Frequency Drives (VFDs)
- Specific pump curves over entire range of operation to achieve optimum pump and motor efficiency and minimum operational costs
- Vibration analysis and monitoring
- The pumps and intake structure also need to be analyzed together especially under the condition of low water levels at the intake in relation to Net Positive Suction Head (NPSH) required and flow paths within the intake structure in order to prevent cavitation of the pumps during operation
- Pump operations within the overall system operation, particularly during rainfall and other high flow events within a watershed impacting system pumping allowance
- Pump controls including the type of control valves and throttling and on/off operation of the individual pumps, or throttling of the pump by means of a control valve to adjust flow, and determination of whether the pump starts against an open (e.g., check valve) or closed valve

1.2.1.3 Pipelines

To some extent, each of the alternatives utilizes a pipeline to convey raw water for all or a portion of its route. These pipelines are of varying lengths depending on the alternative as shown in red on *Exhibit 1*. For Alternative 1, the pipeline is used to convey the water from Lake Livingston uphill to Sand Creek. As shown in *Exhibit 1*, the water could be conveyed by gravity in an open channel the remainder of the distance along Sand Creek and then the East Fork of the San Jacinto River to Lake Houston. For Alternatives 2 and 3, the pipeline is required to convey the water from the Trinity River uphill to a canal. A pipeline is used to convey the water from the Trinity River the entire length to Lake Houston for Alternative 4 and directly to the NEWPP for Alternative 4a.

Alternative 5 includes a pipeline used to convey water from the pump station at SH 146 to Lake Houston. In addition, for Alternative 5a, the pipeline continues directly to the NEWPP. The pipeline for Alternative 6 is used to convey water from the CWA TRPS the entire length to Lake Houston, while Alternative 6a continues the pipeline directly to the NEWPP.

The initial system requirements were developed as noted in the previous section. A preliminary hydraulic review of the pumping and piping system was completed. A summary of the review is included in *Appendix D* in the table – Pump Power Cost. The optimum pipe size for an application minimizes the combined cost of the pipe and its installation, and the power cost to pump water through the pipe. Using the estimated ultimate design flow of 400 MGD, an optimal pipe size on a cost per foot basis was developed to include dual lines of 108-inch diameter reinforced concrete cylinder pipe.

The number, type, and placement of valves along the pipeline are also considered as they relate to the hydraulic capacity of the pipeline.

Given the length of the pipelines in all the alternatives, an important aspect for consideration is hydraulic transients and their possible effects on the pipeline. The methods and mechanisms to address these effects must also be investigated in order to mitigate or prevent their occurrence.

Various materials may be used for pipe including steel and concrete. Various metals may be used in the manufacture of the valves. Due to the volatility of construction materials and labor availability and prices, at this stage of the project, a review and analysis of the advantages and disadvantages of each type of materials would not be appropriate. A complete evaluation of alternative materials of construction will be conducted during subsequent phases.

In summary, initial preliminary engineering issues for pipelines include the following.

- Pipeline location – Environmental constraints influencing the location of the pipeline
- Availability and cost of piping materials
- Corrosion protection
- Surge pressures and presentation
- Inline valves including shut-off valves and vacuum and air-release valves
- Liners and coatings
- Construction methods including open cut and trenchless technology

1.2.1.4 Canals

Several alternatives include the construction of canals to convey raw water by gravity. New canals are included in Alternatives 2 and 3. Alternatives 5 and 5a include improvement to an existing canal.

For a constructed canal, the most important factors to be considered are the shape, material used for lining the canal, elevation and slope of the canal. The alignment, although important, has a larger impact on hydraulics than some of the other factors. Using long stretches of straight reaches is more desirable because it minimizes hydraulic efficiencies and lengths, which equate to lower construction cost and power usage. The shape, lining, and slope of the canal affect the size and capacity of the canal, and must be considered along with their effect on hydraulics at various flow rates. The type of material used affects the roughness of the canal and thus its capacity. The slope of the canal also affects the size of the canal in terms of cross-section as well as velocity. The velocity in the canal needs to be considered as it may affect the degree of erosion on an earthen canal and can influence the rate of sediment transport and deposition, which can affect the capacity of the canal over time. Based on these details, the type of material used to line the canal is critical, whether it is a concrete lined canal, earthen lined, vegetated canal, or some combination of all three. If porous materials are used such as in earthen canals, seepage losses must be considered; if these losses are substantial, additional water must be pumped to offset the losses, thereby resulting in an increase in the overall cost. Decreasing surface area (changing the shape of the canal) or changing the lining material may decrease these losses possibly offsetting the increase in cost of the change in materials. As with open air water transport system, evaporation losses need to be considered as well.

Another point of concern is determining the energy dissipation that is necessary at that point to prevent erosion. In addition, due to decreased velocities from the pipeline to the canal, a centralized location for the resultant sediment deposition must be taken into account.

The elevation of the canal may vary according to the local topography. For example, in Alternative 3, the canal must be able to convey the water by gravity from the end of the pipeline to Luce Bayou near its confluence with Lake Houston. The profile of this alternative is shown in Section 7 of *Appendix B*. To account for varying topography even the canal length at some locations at the top of the canal may be at or near natural ground, while some areas may be elevated as an embankment well above the natural ground which would increase the construction cost of the canal.

More importantly, the elevated embankment may impede the flow of the surface water draining from the area during a rain event. Thus, provisions would be required to place the canal in a location that would minimize impacts to the surface drainage and/or the canal may be constructed with culverts to allow drainage to cross the canal. A detailed hydrologic study will be required to determine the impacts to the area and to identify efforts required to minimize and mitigate those impacts – including revising the location of the canal.

The embankment may also impede access to the land between the canal and Luce Bayou. Provisions would be required to place crossovers at strategic locations to provide adequate access to these areas. Crossing will also impact the construction cost of the canal.

In summary, initial preliminary engineering issues for canals include the following.

- Canal location – Environmental concerns noted elsewhere in this report would impact the location of the canal
- Canal shape
- Canal elevation
- Canal lining
- Sediment and Erosion impacts
- Evaporation and seepage losses
- Surface water drainage impacts
- Crossing
- Ability to acquire land

1.2.1.5 Open Channels

Alternative 1 includes modifications to Sand Creek and Alternative 2 includes modifications to Luce Bayou to improve the carrying capacity of each existing open channel. Open channels have many of the same issues as canals plus several others. When considering the use of an existing channel, the main issue is the capacity of the channel. In sections where there is insufficient capacity, the channel would have to be modified, thus changing its hydraulic parameters.

For Alternative 2, significant modifications to the existing Luce Bayou would be required, including deepening and widening the cross-section and straightening out the channel longitudinally to accommodate the flows. A very preliminary channel hydraulic review is included in *Appendix D.*

Since the base flow in sections of the existing channel will increase when the channel is used for conveyance, channel stability must be investigated. Resulting channel instability due to increased flows can lead to stream bank and bed erosion, and channel movement over time. Therefore, stream bank protection and flow control structures must be considered. Channel movement from the system attempting to reach a dynamic equilibrium could affect future land acquisition.

For Alternatives 1 and 2, another issue is the effect of drainage on the channel during rainfall events. During a rain event, rainfall runoff to the channel would increase the water level. Some control system must be considered so that as flow and water level increase in the channel due to runoff, the pumps at the station would shut down to avoid the flooding. If flooding did occur with the pump station shut down, it would obviously be due only to the natural runoff from the rainfall event and not from contribution from the pump station. This monitoring/control system needs to extend the entire length of the open channel system so that water surface elevation could be monitored at points along the channel, to avoid being impacted by isolated rainfall events.

In addition, when open channels are used, seepage and evaporation losses must be also be considered as mentioned above for canals. In particular, seepage losses, since there is less control over the bed and bank material in natural channels terms of its hydraulic conductivity than for a constructed canal.

In summary, initial preliminary engineering issues for canals include the following.

- Environmental concerns impacting the use of and modifications to existing channels
- Channel shape and hydraulic capacity
- Channel stability
- Evaporation and seepage losses
- Surface water drainage impacts and monitoring

1.2.1.6 Silt Control

The raw water from the lake and/or the river would contain suspended solids. Immediately after the discharge of water from the end of pipe and prior to entering an open channel, a sedimentation basin will be used for silt control. Various types of energy dissipaters at the end of the pipe will be reviewed during subsequent phases.

The sedimentation basin sized to allow quiescent flow so the solids will settle out in the basin prior to entering the canal. This allows sediment removal in a single location rather than in a long canal or Channel Section. The sedimentation basin included in the original design is shown on Drawings 8 and 16 of Section 3 in *Appendix B*. The size and shape of the basin will be defined in subsequent phases of the project based on sediment load and characteristics and available land, etc.

Periodically, solids will be removed from the sedimentation basin. Solids removal requires initial capital costs for equipment and ongoing operations costs for the labor and fuel to operate the equipment and maintenance for the equipment. The solids, particularly sand, may have a commercial value to contractors in the immediate area; however, hauling costs from remote areas will negate commercial value resulting in additional operations and maintenance costs for hauling or additional land for placing the removed solids. Improvements to current CWA sedimentation processes and equipment will be identified and incorporated in subsequent phases of the project.

The sedimentation basin will not remove all solids; remaining solids would settle out from the water to the canal bottom over time. Solids removal in canals also requires initial capital costs for the equipment and operations costs for the labor and fuel to operate the equipment and maintenance costs.

1.2.2 Preliminary Mechanical Issues

Large capacity pumping stations can provide some mechanical challenges due to the size of the pumps, valves, piping, etc.

Preliminary mechanical issues focus on pumps, valves, and piping as the main issues.

1.2.2.1 Pumps

Issues that need to be considered with respect to the pumps include the following.

- Pump type – mixed flow, axial flow, etc.
- Pump performance efficiency, and power usage at rated capacity and head
- Type of bearings and seals
- Method of lubrication
- Materials of construction for pump casing, shaft, impeller, bearings, seals, base, etc.
- Pump and motor speed
- Hydraulics around intake
- Motor size and type
- Availability – worldwide demand for pumps has impacted delivery schedules, overall availability and prices. Alternatives would be reviewed to provide the greatest flexibility in obtaining pumps while meeting service and operational conditions cost effectively

1.2.2.2 Valves

Issues related to valves that need to be considered include the following.

- Valve type – butterfly, gate, check, etc.
- Materials of construction – valve body, stem, bearings, seals, etc.
- Pressure ratings
- If necessary, type of valves and settings for the control of hydraulic transients.
- The type, function, size, etc. of the valves used for pump control, their speed of opening and closing, and the type of automatic actuator to be used with them (e.g., electric, electro-hydraulic, hydraulic with central accumulator).
- Availability – worldwide demand for valves has impacted delivery schedules, overall availability and prices. Alternatives would be reviewed to provide the greatest flexibility in obtaining valves while meeting service and operational conditions cost effectively.

1.2.2.3 Piping

Several issues need to be considered with respect to the piping, and they include the following.

- Alignment – Not only the alignment along the route, but also within the pump station site. Especially the pump discharge lines and header to assure that flow is efficient as well as not compromising the strength and integrity of the pipe.
- Pipe stress analysis – This needs to be considered, especially within the station where piping may be non-buried with many bends, tees, fittings, etc.
- Corrosion protection – Although impressed current cathodic protection could be used where there is a power source, in stretches where the pipeline may be located in an isolated location and power may not be available, either other sources of power need to be considered, or alternative methods of corrosion protection need to be considered.
- Isolation valve placement – Needs to be considered in order to allow for maximum flexibility in operation and maintenance (O&M). In conjunction with this is the placement of access points in the pipeline to allow for either manual or remote visual inspection, cleaning (e.g., pigging), and repair, if necessary, of the pipeline.
- Placement of air release, air/vacuum valves – This needs to be considered to prevent air binding, control hydraulic transistors, and to facilitate filling and draining of the lines.
- Pipe type – Although reinforced concrete cylinder pipe and steel is frequently used in this type of application, the specific conditions of the selected alternative must be examined in detail to determine the best type of pipe to be used for each type of condition along the alignment.
- Availability – Worldwide demand for pipe has impacted delivery schedules, overall availability and prices. Alternatives would be reviewed to provide the greatest flexibility in obtaining pipe while meeting service and operational conditions cost effectively.

In addition to the above issues, the use of chemical feed systems at the pump station needs to be considered. These include chlorine and sequestering or chelating agents. Some of these may be used in either the pumped source water, or in the potable water and On Site Sewage Facilities (OSSF) system.

1.2.3 Corrosion and Cathodic Protection

Exposed materials corrode without proper protection. All exposed equipment, piping, valves, and other metals would be appropriately coated to protect these facilities from corrosion.

Many petroleum/chemical products pipelines cross the study alternatives, and the water conveyance line would cross them. During subsequent phases of the project, careful attention must be given to the evaluation of cathodic protection methods used by each product pipeline so that the proper cathodic protection system is established for the water conveyance line.

1.2.4 Existing Geotechnical Issues

Existing geotechnical issues discussed in this section are based on five geotechnical studies performed within the approximate areas of the considered alternatives. These geotechnical studies do not specifically address the alternatives or routes that are presently under consideration; rather, the purpose of this section is to develop a concept of potential geotechnical issues that may impact the design of the project. A geotechnical study would be conducted at a later date to address specific design issues of the alternative. The five geotechnical studies referred to above are listed below.

- *Preliminary Soils Investigation – Luce Bayou Diversion Project* by National Soil Services, Inc., Report No. 72-288 (February 1973).
- Soils *and Foundation Investigation –Trinity River Pump Station Luce Bayou Diversion Project* by National Soil Services, Inc., Reports No. 72-288-2 and 72-288-3 (November 1973).
- *Luce Bayou Diversion Project – Reidland Dam, Liberty County – Project* by National Soil Services, Inc., Report No. 72-288-4 (January 1981).
- *Geotechnical Engineering Study – Slope Stability and Pipe Anchors Luce Bayou Diversion Project* by National Soil Services, Inc., Report No. 72-288-7 (January 1982).
- *Geotechnical Study – Trinity River Intake Expansion – Coastal Water Authority – Project* by HVJ Associates, Inc., Report No. 02-109GH-0 (January 2003).

These geotechnical studies were intended to define soils stratigraphy along possible piping routes and canals for the Luce Bayou Diversion Project, including the construction of a pump station, and to define slope stability of soils within the construction areas. The predominate type of soils encountered west of Capers Ridge to Luce Bayou at the topstratum are silty sand, clayey sand, and clayey silt. In general, the soils encountered in the locations studied were relatively uniform. Along the piping and canal routes are areas where localized failure can develop during construction due to slough; at these locations, the soils should be replaced. Also, it is anticipated that special shoring would be required during the installation of the pipeline and construction of the canal where excavation would extend into a stratum of medium dense clayey sands while slightly silty.

The construction of the pump station would require temporary installation of sheet pile cofferdams in the river to maintain dry soil conditions. At the same time, shoring may be required during excavation as well. Two types of foundations for the pump station were considered in the geotechnical studies. The first is a load-bearing slab to an elevation that would be determined based on soils analysis of the actual location; it is expected that the excavation would be fairly deep and would thereby require a great amount of excavation and shoring. With this type of foundation, settlements can become an issue and as such would need to be addressed. The use of deep piles is the second type of foundation considered. Driven piles and drilled shafts are two common types that could be used for the foundation supporting the pump station structure. However, there are concerns with the method of construction when installing these deep piles: driving piles would require large equipment and can impact adjacent structures, and drilled shafts may require the use of slurry drilling methods.

It is anticipated that a preliminary geotechnical investigation for the preliminary engineering phase may include but not be limited to the following.

- Conduct field exploratory study including the following:
  - 12 borings at 25 feet depth, 12 borings at 75 feet depth and 12 borings at 120 feet depth
  - 10 piezometers
- Conduct laboratory testing on samples from field exploration.
- Conduct geotechnical analysis and provide design recommendations based on field exploration.
- Develop draft geotechnical report.
- Obtain comments on draft geotechnical report.
- Finalize geotechnical report.

The scope of work for the preliminary geotechnical investigation will be further refined before initiation of work.

1.2.5 Preliminary Civil and Site Issues

The pump station would be located in a remote area, which presents challenges particularly for site access and utilities. In all cases, potable water would be provided by a small well since a public drinking water supply distribution system is not located nearby. For Alternative 5 and 6, the existing water supply would be utilized.

Sanitary sewage disposal would be provided by a small aerobic system and drainfield since a public sanitary sewer collection system is not located nearby. For Alternative 5 and 6, the existing sewage disposal system would be utilized.

An access road would be required from the nearest public roadway to the pump station site. An access road would also be required along the entire length of an open channel, including new canal and improved channels, to allow for maintenance equipment. Existing county and state roadways will be utilized for access when practical.

A fire protection system would be required at the site since a public fire distribution system is not in the vicinity of the pump station site. Housing would also be required on-site due to the remoteness of the area. Drainage for the site would be required for each alternative.

Alternative 1 would be located near FM 224 and access issues for the pump station site would not be as great compared with some alternatives. However, an access roadway would be required for the entire length of the improvements to Sand Creek. The Cape Royale development is near the site; therefore, phone, cable, and other communications may be considered nearby. Water storage and pumping system for fire protection would be provided. Housing would also need to be provided.

Alternatives 2, 3, 4, and 4a include the pump station in a very remote location. An access road would be required from FM 1008 to the pump station site. An access road would also be required along the entire length of the canal and improved sections of Luce Bayou. Water storage and pumping system for fire protection would need to be provided as well as housing along with associated utilities.

Since Alternatives 5, 5a, 6, and 6a utilize the existing CWA TRPS, access roadways to the pump station, utilities, fire protection system, and housing already exist (see site visit dated July 19, 2006, in *Appendix A*). Additional access roadways would be required for portions of the canal. Site drainage already exists for these alternatives as well.

The main civil/site issues that need to be considered are listed below.

- The site layout in order to facilitate access to all areas and efficient use of space.
- Site drainage so that runoff does not adversely affect water quality at the intake structure. Consideration may be given to alternative paving methods to reduce stormwater runoff.
- Accessibility, building, and structure elevations in relation to flood events. Building, structure, and equipment elevations need to be considered with respect to the 100-year flood elevation to assure the continuous operation and protection of the pump station and ancillary facilities from flood waters.
- Because of the isolated location of some of the alternative facilities, centralized water and wastewater services are not available. Therefore, development of a potable water supply for use by operations personnel needs to be considered. In addition, consideration needs to be given to an on-site sanitary sewer facility as well as its effect on source water protection.
- Protection of the intake structure as well as erosion protection resulting from changes to the flow path of the river due to the construction of the intake structure.

- Containment and protection of sources of contamination at the pump station site such a fuels and chemicals used at the site.
- For alternatives with open channels or canals, bridges crossing the open conveyance would have to be constructed to provide landowners access to their land.

1.2.6 Support Facility Issues

Support facilities around a pump station depend on how often the site is visited. If a pump station is operated in the same manner as the existing CWA TRPS, then the new support facilities would need to accommodate staff 24-hours a day, 7 days a week. These facilities should include at least a substantial pump station control room complete with offices for the staff, maintenance building, and an on-site residence(s). For Alternative 5 and 6, the existing support facilities will be utilized.

In addition to the facilities surrounding a pump station, additional facilities would be needed at various locations along the pipeline or canal route. The number and extent of these facilities depends on how often crews need to visit and maintain the route as well as on the length of the route. If crews visit weekly or daily, then a building for offices and equipment storage would be needed. If it is necessary for someone to be on the site at all times, then a residence facility would be considered.

Any new facility would need to comply with Occupational Safety and Health Administration (OSHA) regulations and additional building codes specified by the city and/or county where construction is planned to occur.

1.2.7 Structural Issues

As previously noted, the pump station and intake structure would likely be constructed of reinforced concrete. The design of the foundation for the pump station and intake structure must be closely coordinated with the recommendations included in the geotechnical investigation report. Existing soils types, construction methods, surroundings of the structure, and environmental issues are additional items of concern that will be closely reviewed during subsequent phases of the project. Load-bearing slabs and piles could be considered for a foundation supporting the structure with construction methods dictating a large portion of the design of the foundation. Soil stability analyses must also be conducted prior to design for shoring and bracing purposes.

Due to the volatility of construction materials and labor availability and prices, at this stage of the project, a review and analysis of the advantages and disadvantages of each type of construction materials would not be appropriate at this time. A complete evaluation of alternative construction materials will be conducted during subsequent phases.

1.2.8 Preliminary Electrical, Instrumentation and Communications Issues

Power supply is addressed in the following section. On-site electrical and instrumentation would be common to all of the alternatives.

A Supervisory Control & Data Acquisition System (SCADA) system would be required to assure proper operations of the entire system. Operational conditions along the pipeline, canal, and channel, and at Lake Conroe, Lake Houston, the NEWPP, and the pump station would be collected and shared to allow operators to make decisions regarding pump station operations. These systems can use radio or phone lines for communication systems.

1.2.9 Power Supply Issues

The pumps required for a pump station of this size use a relatively large amount of power. In addition, consideration should be given to a secondary power source. As CWA discovered during Hurricane Rita, a power supply could be easily cut off for days during and after a major storm event while their customers' demand for potable water climbs immediately after the storm passes.

Power supply at the CWA TRPS is adequate for the estimated loads of this project. Additionally, a secondary feed to the pump station has recently been completed. Additional power would not be required for Alternatives 5, 5a, 6, and 6a.

Power supply to the pump station at Capers Ridge for Alternatives 2, 3, 4, and 4a would require extensive effort, but Entergy, the utility provider in the area, has been contacted and their representative indicated that transmission service to the Capers Ridge Pump Station site could be provided. Transmission service is defined as an electrical supply of typically 69 kV and higher feeders with a load greater than 2MW. Industrial customers are usually the recipients of this service. Existing transmission line 562 is located approximately 6.4 miles north of the pump station site and is a 230 kV line running from the town of China to Jacinto.

To request this service from Entergy, a number of details must be provided; they are listed below.

- Layout and location of pump station site
- Layout and location for Entergy-provided substation
  - Entergy would provide dual feed transmission line and fenced substation at location requested by customer
  - Customer must provide fenced 230 kV – 4160 V transformer next to Entergy-provided substation

After receiving the information, Entergy would scope the project which includes the following.

- A permit from Public Utility Commission is required
- Certificate of Convenience and Necessity (CCN)
- The CCN process would be provided by Entergy with occasional input from the customer
- Entergy would provide three routing options to the Public Utility Commission
- All landowners within 300 yards would have one year to voice their opinions on the routing
- There would be an open-house for information and public questions

Entergy would be responsible for all soil samples for power poles required, routing of dual feed transmission lines from existing line to new substation, and construction of new substation. The dual feed transmission lines would be routed from an existing transmission line to a new substation on one path of power poles unless told to do otherwise. If feeders are requested to be routed individually, requiring two separate paths, the customer must inform Entergy of the required separation distance.

- Entergy would perform capacity study on existing transmission line
- CWA must sign contract with Entergy to provide these services

Timing the process of getting a transmission line to a new site is crucial with this project. The CCN would take approximately 18 months. Design would take 6 months. Construction would take a total of about 12 months (12 months for the substation and 3 months for the 6 miles of transmission line). This means that the total time it would take from planning through construction should be about 3 years. However this schedule could be impacted by equipment delivery.

The overall cost to provide power for this project would be approximately $8.5 million. This estimate includes the substation at $1.5 million and 6 miles of dual feed, 230kV transmission line (routed on the same power poles from the existing transmission line) at $7 million. The overall cost would increase substantially if two different transmission line sources are required. It appears that the cost for the line itself is just over $1 million per mile. The location of the next nearest transmission line from which to draw power could substantially raise the costs depending on how far it is from the Capers Ridge Pump Station site.

Alternative power sources considered are additional second power lines from a separate source of power, on-site diesel or natural gas generators, and possibly other sources.

Power supply for Alternative 1 would be similar to that described for Alternatives 2, 3, 4, and 4a.

1.2.10 Site Access Issues

The majority of the alternatives are in rural areas of Liberty County where site access is minimal or non-existent. Roadways would have to be built to maintain access to the site during construction and afterwards during operation. Considerations when designing the access roads include the location of the roads (multiple access points are needed along each water conveyance route), the kind of vegetation that needs to be cleared in the process, whether or not the vegetation needs to be replaced elsewhere, floodplain, drainage and the type of roadway surface (heavy machinery would be traveling on these roads during construction and operation of the facilities). In addition, right-of-way would need to be purchased to accommodate the new roadways.

1.2.11 Potentially Contaminated Areas

Prior to property acquisition, a Phase I Environmental Site Assessment (ESA) would be conducted in accordance with *American Society for Testing and Materials (ASTM) Standard: E 1527-06 Standard Practice for Environmental Site Assessments: Phase I Environmental Site Assessment Process* to identify areas with potential contamination.

1.2.12 Potential Construction Issues

A preliminary constructability analysis of each conveyance system routing/alternative was performed, focusing on the logistical, environmental, terrain (site conditions), utilities, public disruption, specialty construction, and easily discernable capital cost impacts on the actual execution of the conveyance and facility system construction.

While many of the identified constructability issues are common to each conveyance system's routing, significant differences in quantity of constructability issues associated with certain conveyance system alternatives do exist. Construction of pumping, maintenance, and housing facilities would share many of the same conveyance system constructability issues. A list of the constructability issues for all or some of the alternatives are listed below. It should be noted that some of the constructability issues herein identified may be mitigated (one time impact) while others may not.

Constructability issues include the following:

- Remote project site
- Limited existing site accessibility
- Haul road construction and maintenance
- Existing utilities including telephone, power, potable water, and sanitary sewer systems
- Communication
- Weather (i.e., rain and flooding)
- Material and equipment storage area(s)
- Material lay down/staging area(s)
- Site security
- Sufficient temporary construction easements (TCEs)
- Environmental constraints
- Construction in lake or river
- Critical public/private roadway crossings
- Wetland type construction
- Site drainage
- Cedar Bayou crossing
- Pipeline crossings
- Southern Pacific Railroad crossing
- Community disruption or dislocation
- Existing pipeline utility easement area utilization
- Overhead power lines
- Housing development proximity

As previously noted, some of the above identified constructability issues may be mitigated while others may not. Mitigation is defined to be the total or near total elimination, prior to commencement of the work, of a constructability issue impacting the Contractor's ability to perform or complete the work. Mitigation also involves the permanent (with some exception) installation or construction of the mitigating utility or facility. The following route/alternative constructability issues may be mitigated.

Common conveyance systems constructability issues:

- Limited existing site accessibility
- Existing utilities including potable water and sanitary sewer systems
- Temporary material staging and storage/lay down areas
- Sufficient TCEs
- Communication
- Multiple critical/private roadway crossings

It is imperative that these issues be planned for in the selected alternative during design, scheduling, and budgeting, and during land acquisition and permitting. There may be significant time and cost impacts associated with properly mitigating the listed constructability issues.

1.2.13 Project Security Issues

With the heightened terrorist threat in the U.S., it is important to determine the security risks associated with the water transfer project. Contamination through biological agents is especially a concern in open water situations such as canals or channels. At roadway and other crossings along these routes, the raw water from the Trinity River could be contaminated. In addition, the pipeline alternatives would have various points of access along the routes intended for O&M, with which also have the potential for abuse. The issues of source protection also must be detailed. In addition, if the water were contaminated and transported to the lake or the water treatment plant, a series of tests and/or studies would become necessary to determine the impact on the treatment process.

In terms of citizen safety, installation of fencing surrounding the canal would be necessary to prevent accidental drownings from occurring. However, if portions of the project are to be more natural areas and are to be frequently visited by the public, alternative site security issues would have to be addressed. CWA could potentially be held responsible in the event of a drowning or other similar incident and, therefore, should be considered in the evaluation of site security options.

Controlled access around pipeline valve boxes or other pipeline access ports would be necessary to prevent possible vandalization to CWA property where the pipeline is exposed.

1.2.14 Pipeline, Utility, Highway, and Railroad Issues

The potential pipeline, utility, highway, and railroad crossings have been researched and should be taken into consideration along pipeline and canal routes as they could necessitate additional funding for adjustments or rerouting.

Most petroleum/chemical products pipeline companies have developed design and construction standards for crossing of their lines. These may include piping material type, clearances, backfill, construction installation methods, etc. for water lines crossing their facilities. These pipelines can generally be located accurately through either exploratory excavation or probing. For crossings with open channels, the primary issues would most likely be clearances from bottom of canal to pipe, amount of fill on top of the pipe, pipeline personnel access across a canal, etc. Once the route has been selected, the pipeline companies would be contacted to ascertain their standards for incorporation into the project requirements, so approvals could be obtained. In some cases, relocation of the pipelines may be more cost effective. A typical example of a pipeline crossing in Liberty County is shown in *Appendix A* under the site visit dated July 12, 2006.

Private utilities (such as telephone, cable, etc.) generally do not keep accurate records of the location of their infrastructure. Field location is general unless considerable exploratory excavation is completed. This type of infrastructure is often easy to work around or relocate.

Public utilities (gas, water, sewer, etc.) are controlled by local municipalities, special districts, or other utility providers. Field location is usually general and the infrastructure can often be worked around or relocated.

Roadway crossing conflicts would need to be coordinated with the Texas Department of Transportation (TxDOT), Liberty County, Harris County, or other appropriate governmental agency responsible for the specific roadway. Crossings with pipeline would most likely require trenchless construction in TxDOT right-of-ways and potentially in county right-of-ways. Liberty County has traditionally held most of its roadways in prescriptive easements. Crossings with a canal require more extensive construction efforts which may include culverts, bridges, siphons, and other structures. Considerable time would be devoted to addressing concerns of the various entities and obtaining permits and other approvals as needed. Railroad crossings also require permitting and may require a cased tunnel with proper clearances. Considerable schedule time would be devoted to addressing concerns of the railroad company as their permitting process will take months to complete.

1.2.15 Potential Land Acquisition Issues

Liberty County has traditionally been a farming community with timber production and oil and gas development. As such, there is currently limited residential and commercial development in the area. Similarly, eastern Harris County exhibits the same type of development.

Historically, land in Liberty County, and to some extent, far eastern portions of Harris County, has been inexpensive. Growth projections, however, indicate that residential and commercial development of the areas would occur as a result of the overall expansion and growth of Houston. Therefore, it is expected that land prices in the area would rise. As an example, approximately 7,400 acres of land including a portion along Luce Bayou recently sold for approximately $18 million, or approximately $2,500 per acre. For the purposes of this report, a land cost of $5,000 per acre was used due to the smaller tracts of land that are anticipated to be required.

Pipelines and power lines cross the area in numerous locations, leading many land owners in the past to be receptive to providing easements for these purposes. Therefore, it is anticipated that property (easements, right-of-way, etc.) for the buried pipeline would be acquired, provided that fair market value is offered. Acquisition of property for the canal, however, may require more effort, particularly for property owners who may be impacted by lack of access due to the construction of the canals. Prior to property acquisition, it is recommended that a Phase I ESA be conducted in accordance with *American Society for Testing and Materials (ASTM) Standard: E 1527-06 Standard Practice for Environmental Site Assessments: Phase I Environmental Site Assessment Process*.

1.2.16 Capital Construction Cost

The original Luce Bayou project is used as the basis for capital construction costs as shown in *Appendix D* in the table *Constraints Analysis Phase Initial Preliminary Rough Order of Magnitude Planning Level Cost Comparison*. The plans originally completed by KBR were obtained and material takeoffs were completed for the project defined in the plans. Updated material, equipment and other construction prices using 2006 dollars were obtained from various sources including means estimating guides, recent bid tabs, and conversations with contractors to develop an opinion of probable construction cost. Costs associated with the pump stations, open channels, and pipe lines were developed as a probable unit price for each. These unit prices were then applied to the estimated quantities for each identified alternative to arrive at an opinion of probable construction cost.

The key issues with construction costs are as follows.

- Worldwide demand for raw materials, finished materials, equipment, etc.
- Labor shortages
- Long-term survival of piping and equipment businesses

1.2.17 Present Worth Value Discussion

The Present Worth Value of the various alternatives is shown in the *Present Worth Analysis* table in *Appendix D*.

The opinion of probable construction costs are taken from the *Present Worth Analysis* table in *Appendix D*. The land and mitigation costs are rounded off from the values also taken from the *Present Worth Analysis* table in *Appendix D*. Engineering, financial, and legal costs were estimated to be 25 percent of the total of the construction, land, and mitigation costs. The total capital costs include the opinion of probable construction costs, land costs, mitigation costs and engineering, financial, and legal costs. The total capital costs were annualized over five different periods – 20, 30, 50, 75, and 100 years.

Annual power costs are taken from the *Pump Power Costs* table in *Appendix D*. Annual canal maintenance costs were taken from the *Canal O&M Costs* table in *Appendix D*. Annual pipeline maintenance costs were estimated at 1 percent of the construction costs. Total annual costs include power, canal maintenance, and pipeline maintenance costs.

The present worth value of the capital and annual costs were determined over 20- and 30-year periods. Costs were shown in both 2006 and 2012 dollars.

1.2.18 Preliminary Operation and Maintenance Issues

A summary of O&M issues and associated costs could be seen in *Appendix D*. This summary was created after gathering information from various resources, which primarily include CWA's staff at the TRPS and canal.

Major issues pertaining to the O&M of a pump station include the following.

- Routine maintenance of pumps, valves, and actuators (See *Figure 1*)
- Cleaning of bar screens (See *Figure 2*)
- Cleaning of the sedimentation basin (See *Figure 5*)
- SCADA system – monitoring and maintenance

Additional information regarding the O&M of the pump station and canal could be seen in detail in the site visit dated July 19, 2006, in *Appendix A*.

Figure 1. The Coastal Water Authority's Trinity River Pump Station

Typical pumps, lubrication of these pumps are performed every two hours daily to keep the pumps operating smoothly.

Figure 2. Bar Screens at the Trinity River Pump Station

Bar screens are located near pump intake and are cleaned daily.

Major issues pertaining to the O&M of a canal include the following.

- Mowing maintenance berms continually for eight months a year (See *Figure 3*)
- Clearing vegetation out of siphon screens once each week (See *Figure 4*)
- Clearing vegetation out of canal as needed
- Inspection, maintenance, and repair of breeches along the berms
- Employees to perform these tasks
- Equipment purchase and regular maintenance
- Valve exercise

Figure 3. Coastal Water Authority's Canal

Mowing occurs weekly during peak months (March through October). Notice canal walls eroding; repair of banks is often necessary and is performed regularly.

Figure 4. Siphon Screens at CWA's Canal

Weekly cleaning of siphon screens is required at CWA's canal. Build up of vegetation can slow down the water and cause clogging of siphons and backup of water. Backhoes are used to remove vegetation.

Figure 5. Settling Basin Downstream of Pump Station Intake

Directly downstream of pump station intake, at the beginning of the CWA canal, there is a settling basin that keeps silt in the canal at a minimum. It has to be dredged yearly using large machinery and requires disposal of large volumes of dredged material.

Major issues pertaining to the O&M of a pipeline include the following.

- Periodic inspection of pipeline to ensure no water loss along route
- Periodic cleaning of pipeline to remove obstructive deposits within the line
- Mowing of maintenance right-of-way
- Employees to perform these tasks
- Equipment purchase and regular maintenance

Major issues pertaining to the O&M of an open channel include the following.

- Periodic inspection of channel to clear bridges and culverts of debris (See *Figure 6*)
- During a storm event, pump station operator must be aware of potential for flooding downstream and shut down the pumps if conditions are threatening
- Mowing of maintenance right-of-way
- Clearing of fallen trees (See *Figure 7*)
- Employees to perform these tasks
- Equipment purchase and regular maintenance

Figure 6. Luce Bayou at SH 321

Removal of debris at bridges and culverts requires large maintenance equipment and disposal of material removed.

Figure 7. Luce Bayou Downstream of SH 321 and Reidland Dam

Fallen trees are common in remote locations along the bayou.

1.2.19 Summary of Engineering Work

After gathering data associated with Alternatives 1 through 9 and reviewing the details, it is evident that from an engineering perspective, all alternatives are technically feasible. Therefore, the opinion of probable construction cost (developed in Section 1.2.16 above) became the limiting factor in determining the most viable alternative. In terms of the estimated construction cost, Alternatives 1, 2, and 3 are the most practical. Present day construction costs for Alternatives 1, 2, and 3 are $195 million, $160 million, and $175 million, respectively (See *Appendix D Constraints Analysis Phase Initial Preliminary Rough Order of Magnitude Planning Level Costs Comparisons* table). These costs are lower compared to Alternatives 4 through 6a at costs that range from $355 million to $940 million.

As mentioned previously, the difficulty of obtaining water rights for Alternative 1 eliminates it as a possible alternative. The difficulties of obtaining such water rights are costly, time consuming, and would require major impacts to the project schedule. Assuming the clerical issue regarding water rights at the Capers Ridge Pump Station site is easily resolved by the City of Houston, the remaining Alternatives 2 and 3 appear to be the most feasible based on these preliminary costs.

1.3 Limited Site Reconnaissance

Limited site reconnaissance trips were conducted from July through November 2006 to gain an understanding of the alternatives, potential environmental issues, and feasibility. During site reconnaissance visits, various locations along Luce Bayou, Dayton Canal, the CWA TRPS, and several pipelines routes were inspected and discussed. Most of the site reconnaissance investigations were primarily focused on Alternative 2 (Luce Bayou). During two field trips, CWA facilitated site access with local landowners who allowed the project team to access areas of Luce Bayou that were previously inaccessible. During these field trips, the site observation of Luce Bayou began west of SH 321 and continued in a southwesterly direction on available road or utility crossings. The most westerly site visited was east of FM 2100. Meeting notes and detailed information pertaining to the limited site reconnaissance conducted are provided in *Appendix A*.

The Luce Bayou corridor is heavily vegetated with tree falls and woody debris a common occurrence. Bald cypress is present along much of the channel downstream of the confluence of Luce Bayou and Tarkington Bayou. Soils along Luce Bayou are primarily sandy. Within the headwaters east of SH 321, the Luce Bayou channel is typically narrow and shallow with frequent indications of channel erosion. Downstream of Tarkington Bayou, the channel becomes wider, but continues to exhibit indications of erosion. Tree falls and woody debris are common along Luce Bayou. In the mid portion of the corridor, a small dam (Reidland Dam) impounds a portion of flows within the channel. Immediately upstream of the dam, the channel is wider and deeper than typical. As Luce Bayou approaches Lake Houston, the normal pool elevation of the lake extends into the lower portion of the Luce Bayou channel. The channel is much deeper and wider in this area.

1.4 Constraints Analysis Screening

An environmental constraints matrix was developed to provide a quantitative evaluation of the nine alternatives identified for the Luce Bayou Interbasin Transfer Project. The environmental constraints matrix includes columns representing (1) environmental criteria used for evaluation, (2) weighting factors for each criterion, (3) screening limits for each factor, and (4) the calculated result based on the environmental criteria for each alternatives. The environmental criteria are those environmental resources for which suitable existing data are available at the preliminary screening level; the criteria do not include those features that would require extensive field reconnaissance and/or agency consultation, both of which would be conducted after the screening level of the alternatives study.

The weighting factors represent the relative importance of the various constraints criteria. TCB INC. (TCB) environmental staff and engineering staff collaborated to develop the weighting factors in the context of ecological consequences, permitting issues, project schedule, and project cost. TCB staff established screening limits for each criterion based on a combination of (1) environmental and engineering issues that may impact the project and (2) clear breakpoints between measured criteria.

The environmental alternatives matrix (*Table 3*) summarizes the results of the initial constraints alternatives analysis. Each criterion that was calculated was tallied to create a total score or rank for each alternative. The total score is the sum of each criterion meeting or exceeding the screening limit when multiplied by the corresponding weighting factor. The minimum weighting factor possible under the given conditions is zero, and the maximum score is three.

Each criterion that exceeded the screening limit was assigned a value of one point; those that did not exceed the screening limit were assigned a value of zero points. After points were assigned, they points were multiplied by the weighting factors and summed for each alternative to determine a score. The alternatives were assigned the following scores with the lower scores being reflective of more favorable construction and potential environmental constraints related to project implementation based on the criteria selected for analysis.

- Alternative 1 – 12 points
- Alternative 2 – 10 points
- Alternative 3 – 6.5 points
- Alternative 4 – 14 points
- Alternative 4a – 18 points
- Alternative 5 – 11.5 points

- Alternative 5a – 17.5 points
- Alternative 6 – 11 points
- Alternative 6a – 13 points

Inherent in the project development is the concept that the project would have the potential to impact waters of the United States, including wetlands, and therefore be subject to permitting under Section 404 of the Clean Water Act. The USACE can issue one of two types of permits for activities that may impact jurisdictional waters of the United States, including wetlands. General permits, including nationwide permits (NWP), are a set of standardized permits for specific, limited scope activities. Because of the size and scope of the project, the project would need to be reviewed by the USACE to determine if this type of permit would be applicable to authorize project activities. An Individual Permit (IP) is used to evaluate, on a case-by-case basis, those projects with structures or work in regulated waters of the United States to determine if the project is in the public interest. This type of permit requires a public interest review, including public notification and coordination with involved government agencies, interested parties, and the general public. Both types of permits require Section 401 water quality certification from the state (i.e., TCEQ).

The Clean Water Act directs the USACE to evaluate projects for the least environmentally damaging practicable alternative. The practicality of alternatives has been assessed by the determination of whether the identified alternatives are available to CWA in terms of cost, logistics, and technology in light of overall project purpose (i.e., the purpose of and need for the project). To address the practicality of alternatives, TCB has documented the following:

- Cost: An alternative is practicable with respect to cost if it would allow for stable and predictable water costs.
- Logistics: An alternative is practicable with respect to logistics if it provides a water source/supply that is legally accessible, could be transported, and is of a suitable quality and quantity to represent a dependable supply.
- Existing technology: An alternative is practicable with respect to technology if it is compatible with existing equipment and technology for extraction and transport of water, and does not require major expenditures of capital for new equipment and technology.

Alternatives described as Alternatives 2 and 3 have been identified as meeting the practicable alternatives test given cost constraints, availability, and technology. Alternatives 2 and 3 have been carried forward to the alternatives analysis presented in Section 2.

Table 3. Constraints Matrix

Criteria	Weight	Screening Limit	Alt 1	Alt 2	Alt 3	Alt 4	Alt 4A	Alt 5	Alt 5a	Alt 6	Alt 6a
Agricultural Data											
Length (ft) through prime farmland soils[1,2]	**1**	**89,000**	800	91,400	91,200	98,700	112,200	99,800	113,500	89,200	107,000
Biological and Habitat Data											
Length (ft) of parks, state/federal forests/ WMAs intersecting alternative[1]	**1.5**	**5,280**	203,800	9,900	9,900	9,900	9,900	0	0	14,800	14,800
Riparian habitat (ft)[1]	**1.5**	**5,280**	325,000	106,500	NA	NA	NA	NA	NA	NA	NA
Waters of the United States (including wetlands) Data											
No. of drainage or canal crossings	**1.5**	**10**	2	1	5	10	10	16	16	20	20
Length (ft) of stream within alternative[1]	**0**	**N/A**	327,900	106,500	NA	NA	NA	NA	NA	NA	NA
Length (ft) of NWI wetlands intersecting alternative[3]	**0**	**N/A**	0	36,400	24,500	8,800	19,600	23,000	33,800	12,900	21,000
Length (ft) of mapped floodplains intersecting alternative[1]	**0**	**N/A**	319,900	120,200	23,200	14,300	24,200	17,900	27,800	17,900	31,200
Length (ft) of NWI wetlands intersecting mapped floodplains[3]	**2**	**5,280**	0	34,100	5,700	0	9,800	3,800	13,600	2,400	4,700

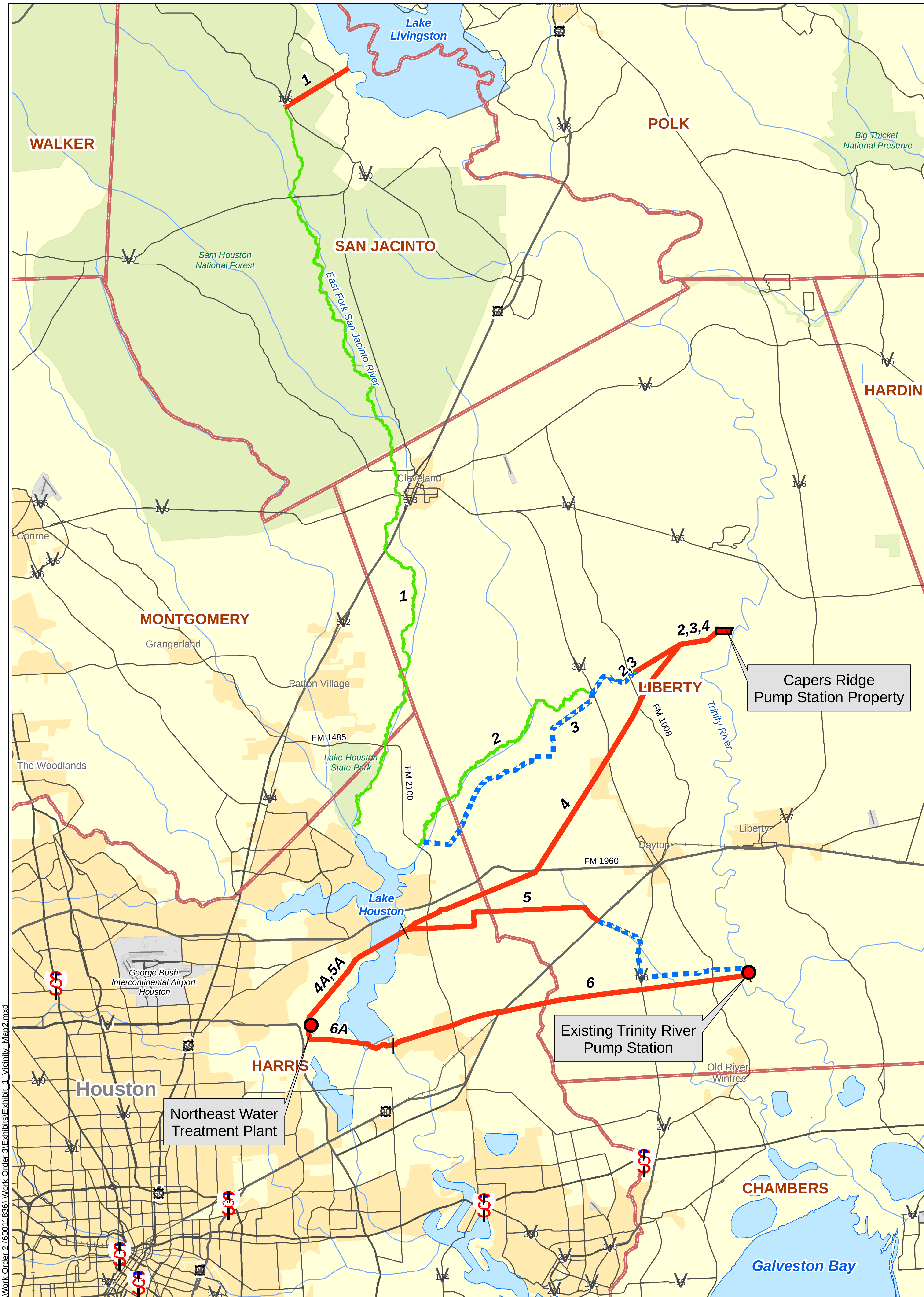
Table 3. Constraints Matrix *(continued)*

Criteria	Weight	Screening Limit	Alt 1	Alt 2	Alt 3	Alt 4	Alt 4A	Alt 5	Alt 5a	Alt 6	Alt 6a
Environmental and Socioeconomic Data											
Length (ft) through minority census tracts[1]	**0**	**26,400**	None	74,300	61,300	37,300	26,400	None	26,400	None	None
Length (ft) through low-income census tracts[1]	**0**	**N/A**	None	None	None	None	None	None	None	None	None
No. of potential dislocations[7]	**0**	**N/A**	NA	NA	NA	NA	NA	NA	NA	NA	NA
Hazardous Materials Data											
No. of TCEQ listed Superfund sites within 500 feet[4]	**1**	**1**	0	0	0	0	0	1	0	0	0
No. of mapped oil and gas wells within 500 feet	**1**	**12**	NA	3	3	16	21	9	14	14	15
No. of pipeline corridor crossings for each alternative	**1**	**19**	NA	12	14	19	20	21	22	20	23
Engineering, Permitting, and Logistical Data											
New Pump Station Required (Y or N)	**2**	**Yes**	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No
Pump Station Modifications Required (Y or N)	**2**	**Yes**	No	No	No	No	No	Yes	Yes	Yes	Yes
Additional Water Right Permitting Required (Y or N)	**3**	**Yes**	Yes	No	No	No	No	No	No	No	No

Table 3. Constraints Matrix *(continued)*

Criteria	Weight	Screening Limit	Alt 1	Alt 2	Alt 3	Alt 4	Alt 4A	Alt 5	Alt 5a	Alt 6	Alt 6a
Surface/subsurface conveyance (percent)	**1**	**90/10**	90/10	80/20	77/ 23	100/0	100/ 0	48/ 52	48/52	40/60	0/100
Permanent alteration to area drainage	**0**	**N/A**	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
Length of Improvements	**1**	**116,200**	17,600	96,000	115,900	126,300	167,200	112,900	153,900	114,200	130,200
Estimated construction cost (millions)[5,6]	**3**	**$300**	$195	$160	$175	$470	$940	$355	$720	$390	$655
Estimated operation and maintenance cost (millions)[5,6]	**1**	**9.2**	9.9	8.7	8.7	9.2	12.0	7.2	9.8	8.6	9.8
Estimated Mitigation Cost (millions)[5]	**2**	**5.0**	8.4	13.1	4.5	4.0	6.3	4.5	6.0	3.0	4.5
Total Weighed Score			12	10	6.5	14	18	11.5	17.5	11	13

[1] Numbers are estimated to the nearest 100 ft for the distance of the intersection of the alternative and the environmental constraint.
[2] Prime farmland soils include soils that are classified by the NRCS as prime farmland or prime farmland if drained.
[3] Numbers are estimated to the nearest 100 ft.; NWI-mapped wetlands are not inherently jurisdictional and accurate. Actual wetland size and location would vary.
[4] A single location may comprise one or more sites depending upon types of materials handled and database registry. Information is based on EPA and TCEQ GIS data sets.
[5] Costs subject to change, pending additional information.
[6] Numbers based on ultimate design (400 MGD), 2006 dollars
[7] See Section 2.1.9



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Source - ESRI (2002)

Legend
- County Boundary
- Pipeline
- Canal
- Existing Natural Channel
- Facilities

0 25,000 Feet

Luce Bayou Constraints Alternatives 1 through 6a

Vicinity Map

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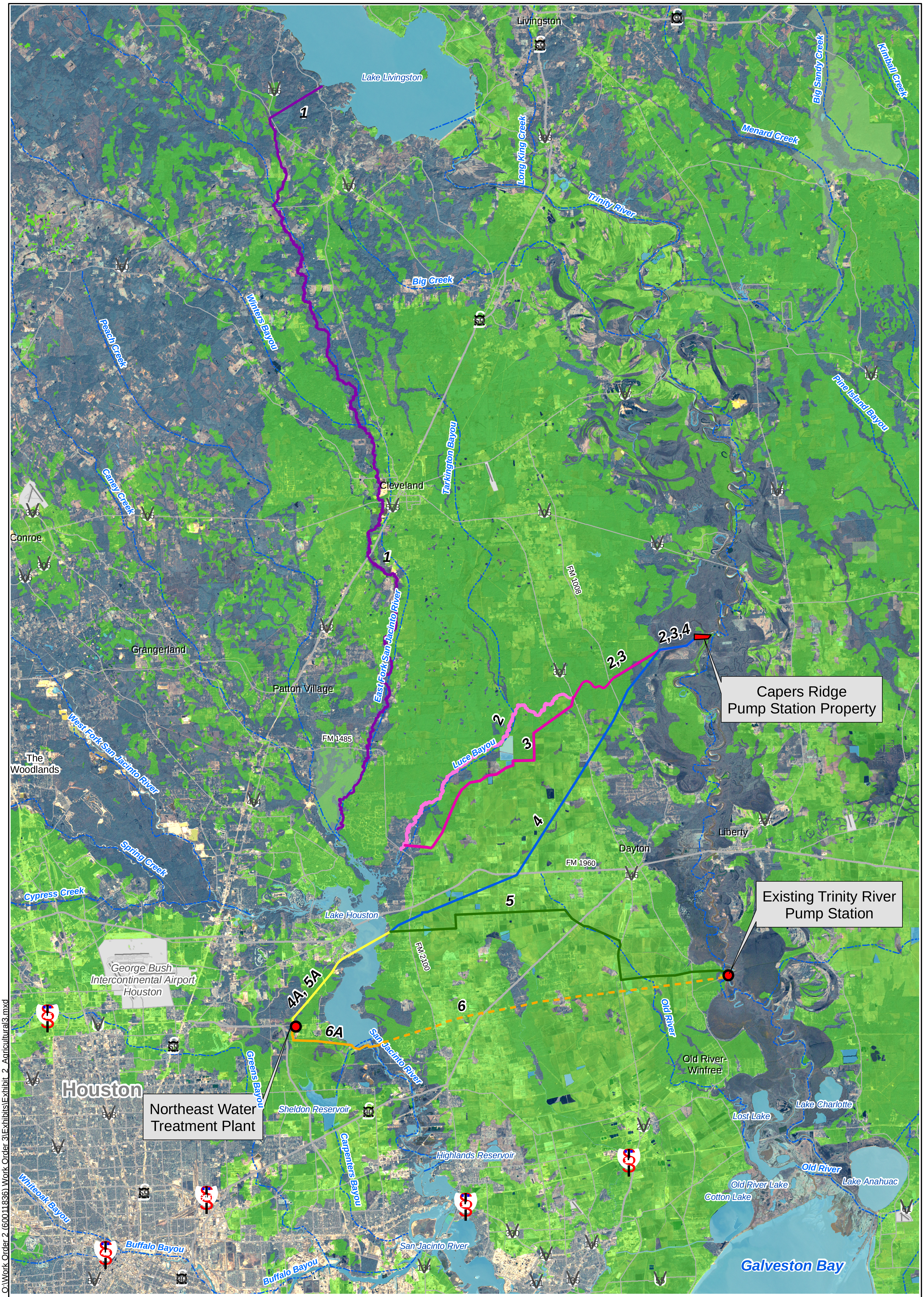
Exhibit 1 Job No. 60018609 Date January 2007



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Source - Imagery from Texas General Land Office (Landsat 2003)

Legend

- Prime Farmlands
- Facilities
- Alternative 1
- Alternative 2
- Alternative 3
- Alternative 4
- Alternatives 4A, 5A
- Alternative 5
- Alternative 6
- Alternative 6A

0 25,000
Feet

Luce Bayou Constraints
Alternatives 1 through 6a

Agricultural

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2	60018609	January 2007